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EDITORIAL NOTES.

As will be seen from the official report reprinted elsewhere in this issue, the Geological Society has decided at a Special General Meeting to admit women as Fellows. It was generally believed that the result was a foregone conclusion, and the figures of the ballot indicate that this belief was justified. As the President pointed out in his opening remarks, the Society has in the past pursued a rather hesitating policy with regard to this matter, and it is satisfactory to find that a clear and definite decision has at last been made on a motion initiated by the Council. The work done in the past by a number of women geologists has been of a high order of merit, and the recognition of its worth will doubtless stimulate others to follow in similar paths and even to surpass the achievements of the pioneers. Ere long we shall doubtless see ladies occupying seats on the Council and possibly even the presidential chair.

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We have much pleasure in calling special attention to the paper appearing in this number of the Magazine under the title of "Foliation and Metamorphism in Rocks". In this Professor Bonney gives a summary of the conclusions reached by him after an almost lifelong study of the subject both in the field and in the laboratory. It so happens that Professor Bonney's active geological life nearly synchronizes with the existence of microscopic petrology; he was one of the pioneers in this field and has had unrivalled opportunities of examining the gneissose and schistose rocks of many parts of the world, and especially those of the Alps. Again, he has devoted much attention to the origin of serpentine and cognate questions, both in Britain and abroad, with important results. Among other achievements Professor Bonney was one of the band of geologists who set British stratigraphy free from the incubus of "altered Silurian", and assisted to exorcise many other bogeys surviving from an earlier day. We feel sure that our readers will welcome this summary of the conclusions reached by one of the masters of petrology after nearly half a century of research, all the more because the observations on which the results are founded are entirely first-hand and independent of textbooks or preconceived ideas of any kind.

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Following a deputation to the Board of Trade from the Joint Industrial Council for the Tin-mining Industry of the United Kingdom, the Government delegated to the Imperial Mineral Resources Bureau the duty of making a preliminary inquiry into the position of the industry, which is, as is well known, in a parlous condition owing to the high cost of labour and material, without a corresponding increase in the price obtained for the main product of the mines, namely black tin or cassiterite. A committee was formed to undertake the work, Sir Lionel Phillips being appointed Chairman, and Dr. F. H. Hatch and Mr. W. Forster Brown, on behalf of this Committee, have recently visited the principal mines in the Camborne–Redruth area as well as those near St. Just and St. Agnes. At their request they were supplied with full data relating to the operation of the mines in the years 1912–18 inclusive. We understand that the report of the Committee, after approval by the Bureau, has been placed in the hands of the Government, and will be considered as soon as possible.

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The lecture recently given by Professor Edgeworth David before the Geological Society gave food for a considerable amount of reflection on the importance of geology in warfare and the extraordinary inability of our military authorities to appreciate this importance. It was, however, fully realized by the Germans, who had a geologist for every 20 kilometres, as against one geologist for the whole of the British western front. This responsible post was held by Captain W. B. R. King, of the Geological Survey of Great Britain. On occasion Professor David also assisted with advice on geological matters, especially with regard to water supply, but as a rule no geologist was consulted until borings in unsuitable places had failed to find water, thus wasting time, labour, and money. Expert geologists were also urgently needed to advise with regard to tunnelling and mining operations; owing to ignorance of the position and depth of the water-table tunnels were frequently drowned out. A water-table map of most of the western front was eventually constructed, but it was impossible for the small staff to deal adequately with this and many other matters, such as prospecting for road-metal and other necessary supplies. Although many geologists were actually serving in the Army in various capacities on the western front, Headquarters did not seem to think that their services could be usefully employed; some of the Engineers high in authority did, however, realize the value of geology and would have liked more help, as is made manifest in a paper entitled "The Work of the Miner on the Western Front", read by Major H. Standish Ball before the Institution of Mining and Metallurgy on April 10, and published in the Bulletin of the Institution for last month. This contains some brief but highly appreciative remarks on the geological work of Professor David and others. The general conclusion to be drawn is that professional geologists ought to be permanently attached to all armies.

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Owing to the unprecedented demand for houses, a large amount of indiscriminate building will take place in the immediate future. A recent issue of the *Observer* contains a most timely article, signed "Silex", on the necessity for geological advice and control in these matters. There are few subjects on which more nonsense is talked and written than on the question of the suitability or otherwise of various soils for residential districts. The general public has acquired some vague ideas as to the advantages of gravel soils and the supposed evil effects of clays, but the importance of taking into account other conditions as well is hardly ever realized. The man in the street is by no means aware that a gravel site in a hole, such as the Thames Valley, may be infinitely wetter and more unhealthy than a clay site on a hill, and similar instances might be multiplied indefinitely. It is highly desirable that local authorities before giving their consent to building schemes, at any rate on a large scale, should consult an expert as to the suitability of the area suggested for the special purpose in view, and that they should refuse their consent in the case of an unfavourable report. Neither municipalities nor the State can afford to allow the health of the people to be endangered or money tc be wasted in unprofitable and possibly injurious enterprises, when this can be prevented by sound scientific and technical advice.

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Mr. T. Sheppard has again earned a debt of gratitude for a remarkably interesting sketch of Martin Simpson and his career. He provides a pedigree, bibliography, and detailed description of his books and a variety of personalia now difficult to obtain, a facsimile of his writing and the well-known portrait. The paper appears in the Proceedings of the Yorkshire Geological Society, xix (4), 1918.

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Dr. H. S. Washington contributes to *Art and Archæology*, vii (7), August, 1918, 256–63, a description and figures of a medal he acquired in Rome. Of Leonello Pio, Count of Carpi, it is cast in lead, and dates from about 1500. The artist is unknown. The special interest of this medal lies in the fact that it represents a volcanic eruption, with "lightning-charged" clouds, falling bombs, and lava-flow in realistic fashion, and Washington, from a most careful and elaborate investigation, thinks that it must represent the eruption of Vesuvius of 1500, described by Ambrosio Leone in *La Storia di Nola*, 1514, which contains the oldest known figure of Vesuvius. If that is so, then the medal is probably a little earlier in date than the book. The legend on the reverse, surrounding the design of the mountain, reads MELIUS PUTATO, which Washington interprets as "more powerful (or active) than I have been thought to be", and he further points out that as the records of earlier eruptions are 1036, 1049, and 1139, the motto would be appropriate to the popular idea that the volcano was then extinct.

ORIGINAL ARTICLES.

I.—Foliation and Metamorphism in Rocks.

By Professor T. G. Bonney, Sc.D., LL.D., F.R.S.

Introductory.

THE application of the microscope to petrology made it possible to investigate effectively the history of the foliated rocks and of metamorphism. This was done, as it happens, only a very few years before I began any special study of such rocks, so that the account of my own work almost corresponds with that of the general progress in a knowledge of them. I was led, after some preliminary efforts, into investigating two distinct problems, each of which, as I soon discovered, presented rather exceptional difficulties. These were the pre-Carboniferous rocks of Charnwood Forest and the serpentines of the Lizard. The problem involved in the one was how far some of them were or had been igneous in origin, lavas, tuffs, and agglomerates, or were stratified rocks, which by pressure and mineral changes had been so altered as to be indistinguishable from some of the former. The other introduced the question of the origin of serpentine, about which in 1873 the utmost uncertainty existed.[1] This, from its associations, led on to investigating the nature and origin of gneisses and schists, so that the history of my own studies during the last forty-five years happens to illustrate some important aspects of the progress made during that period. So I have thought that even now, notwithstanding the multiplication of textbooks and special memoirs (nay, perhaps because of it), some younger students may find it both interesting and useful to read the conclusions which I have been led to adopt, and to have their attention directed to investigations which were, to a large extent, independent and unbiassed.

As my first paper depending on microscopic work was published early in 1877, anyone who consults those which have since appeared must not be surprised to find that my conclusions have been reached by degrees, and that some have had to be retracted. The former should be forgiven, because one frequently resembled a man feeling his way through a dense forest and the latter was often due to misleading information. More than once I have found that the old saying "put not your trust in princes" is true even in science. Of both these defects my work in Charnwood and at the Lizard affords instances. In the latter it was long before the real history,

[1] The following remarks appeared in *Rocks, Classified and Arranged* (B. von Cotta; translated by P. H. Lawrence and published in 1866 with author's preface of same date). After stating that serpentine is "probably the product of the metamorphosis of some other rock", he continues (p. 317): "In some places . . . its transmutation from other rocks is very evident, as, for instance, from gabbro at Siebenlehn, near Freiberg; from dykes of granite traversing serpentine rocks near Böhrigen and Waldheim in Saxony, where the main serpentine itself is not improbably a transmuted granulite; from chlorite-schist at Zell in the Fichtelgebirge, where the change does not appear to be yet complete; and from gneiss (probably) or an eclogite rock in the gneiss at Zöblitz in the Erzgebirge."

as I believe it to be, of its gneisses and hornblende schists came home to me. The same holds good of the Alps, but in one paper relating to them, that on *The Carboniferous Gneiss at Guttannen*,[1] I doubt if I have not fallen into one error while trying to correct another. Besides studying the slab supposed to contain two small tree stems in the Berne Museum, I visited Guttannen in 1891, 1895, and 1897, and in the last year saw an outcrop of the "Carboniferous gneiss" in the Urbach-thal. But it has since been proved that these objects are not fossils of any kind.[2]

How the Problems arose.

On beginning to give lectures in Geology just half a century ago, I soon discovered how little I knew about that part of it which is now called petrology, and that the authors of the textbooks then in use were in much the same position. In England De la Beche, in Scotland Macculloch[3] had done most valuable work, but with their deaths not only had progress been arrested but also a movement had begun in a reverse direction.

The application of the microscope to the study of thin slices of rocks, for which we are indebted to the inventive genius of H. C. Sorby,[4] arrested this movement and gave the student a surer footing. I began to work with this instrument about 1870 (tentatively at first, because at that time my eyes were far from strong), and for a while restricted myself to the igneous rocks, but I was soon drawn into those of the metamorphic group and was speedily confronted by statements which, as I was not long in finding, rested on very uncertain evidence. This forced me to enlarge my field of examination. Charnwood, as I have said, soon presented one set of problems, the Lizard another. The difficulties of the Llanberis district resembled the former, those of Anglesey to some extent approximated to the latter. Specimens sent to me by friends directed my attention to the alleged metamorphism in South-Western Ayrshire and in the North-Western Highlands, and I sought light on the difficulties of the latter by studying the gneisses and schists of the Alps, among which I often spent a summer holiday.

Thus having done what I could, for nearly forty years, by work in the field and with the microscope, to solve some of the problems presented by the metamorphic rocks, I have thought that perhaps a short record of the results might be useful. It contains, I fear, nothing new; probably everything in the following pages "has been said by somebody somewhere", but I may at any rate plead that my conclusions have not been taken "second-hand". As a rule,

[1] Q.J.G.S. xlviii, p. 390.

[2] The story of this "Comedy of Errors" is told in "Plant Stems in the Guttannen Gneiss", Geol. Mag. 1900, p. 215.

[3] J. Macculloch died in 1835, H. T. De la Beche in 1855, but the clouds were gathering again before the latter date. An excellent account of the difficulties which had to be encountered by those who were living and working in the earlier half of the nineteenth century is given by Sir A. Geikie in *The Founders of Geology*, ch. viii.

[4] He began this work, for some years little appreciated, about 1850.

I have consulted memoirs and textbooks only so far as to obtain a statement of the problems and to ascertain what places were likely to throw light upon them, and on this account ask my readers, if they think my conclusions wrong, before rejecting them contemptuously because they are unorthodox, to "go and see"—to examine nature for themselves, to collect their own specimens, and to study them with the microscope.

Foliated Rocks.

Foliation denotes a structure due to a more or less parallel ordering of certain of the mineral constituents in a rock which is not a direct consequence of its stratification. Such rocks are commonly called metamorphic, but that structure, as we shall see, is more often an original one than was once supposed. In a certain sense all rocks, except recent volcanic ejections and such sedimentaries as wind-blown sands and dusts, or diatomaceous earths, coral-reef limestone and even pure chalk, are metamorphic, because they have undergone some amount of mineral change since the time when they were first deposited. In a sandstone, for instance, the fragments are cemented by a little secondary quartz or iron-oxide; in a limestone those of calcareous organisms are united by calcite; in an igneous rock the less stable minerals have undergone some change, but we do not consider this as amounting to metamorphism. To justify the use of that term, the bulk of the constituents, all in fact which are small in size, should have lost the aspect which was once characteristic; for instance, in a limestone the calcareous organisms should be no longer recognizable as such, and any constituent mud should have been converted into a mica or some other authigenous mineral. This may, however, happen, as we shall presently see, without resulting in a definite foliation. But in certain igneous rocks such a structure may be, not a superinduced, but an original one.

Foliation, then, is produced by a parallel ordering of the authigenous platy or acicular constituents in a rock, and may or may not be associated with mineral banding.[1] In the simpler case, when the constituents are not thus grouped, we find that the foliation is the result of movements in the mass, before it has become completely solid, though after most of its component minerals had segregated. Banded foliation, however, proves to be due, at any rate in many cases, to the movement of two associated magmas, different in chemical composition, both of which are in a somewhat plastic condition, though one may be more nearly liquid than the other. The two are forced along, sometimes without mixing, as two differently coloured glasses may be in the hands of a glassblower. Many varieties of rock, from acid to basic, from vitreous to holocrystalline, afford examples of this structure.

I have studied its various stages in several places, of which the following may serve as examples. (*a*) On the southern half of Kennack Cove (Lizard) we can see veins of a grey granite breaking up a dark slightly foliated biotite-diorite, which it partly melts

[1] See *Manual of Geology*, J. B. Jukes, 1872 (ed. A. Geikie), p. 142.

down, till a well-banded gneiss results from the movement of the imperfect mixture (**1**).[1] (*b*) A similar gneiss occurs in Kynance Cove and the cliffs to the south, though here the first stage is not so well illustrated (**2**). (*c*) In Sark, on both the east and west coasts, we find a similar banded gneiss, produced by the intrusion of an aplitic granite into a basic diorite or hornblendite (**3**). The hornblende schists of the Lizard and of Sark also suggest a similar origin, viz., that after a moderately basic magma has been separated by differentiation into a more acid and a more basic part, the two, while still in a pasty state, have been forced to flow together (**4**). The different stages (*d*) of this process are very well displayed on the ice-worn rocks at the foot of the Allalin Glacier in the upper part of the Saasthal (**5**). Here a rather fine-grained aplite breaks into a mass of *grüner Schiefer* (probably a pressure-modified diabase). Sometimes the one rock simply forms veins in the other; sometimes the former breaks off fragments from the latter; sometimes it melts part of these, producing locally a fine-grained green-streaked gneiss. A process generally similar may be studied (*e*) in the rocks under Castle Cornet, Guernsey (**6**). Thus, as gneisses and hornblende-schists, exactly resembling those of which the genesis can be observed in the field and under the microscope, are by no means rare, we seem to be justified in concluding that this production of banded gneisses by partial mixture of more or less plastic magmas is one of frequent occurrence.

b. Foliation also may be produced in an ordinary holocrystalline rock by the action of pressure, more or less definite in direction, and sufficiently great to cause a partial crushing of the mass, which is succeeded by the formation of new minerals. Sharply folded rocks, such as often abound in mountain ranges, afford many examples of this kind of foliation. Here the quartz is more or less crushed; so also is the felspar, but this mineral, by the subsequent action of water (doubtless when the pressure was diminishing), is replaced by a mixture of granules of quartz and small scales of a white mica, the latter generally lying at right angles to the direction of pressure. Thus a granite may exhibit all stages from an ordinary gneiss to a mica-schist (**7**), and a porphyritic granite those from an augen-gneiss to one characterized by thin and rather minutely crystalline bands (**8**). The so-called protogine of the Alps, which, instead of being the "first-born" of their crystalline rocks, is intrusive into great masses of a more or less banded gneiss (sometimes rather rich in biotite), affords excellent examples of this, as in the Mont Blanc range (**9**), on the upper part of the St. Gotthard Pass (**10**), and in more than one district of the Engadine (**11**).

One form of "pressure-gneiss" deserves special notice, because, till about thirty-five years ago, its origin was a geological puzzle. Of this the so-called Newer Gneisses of the North-West Highlands are an historic example. These appear to overlie the basal Cambrian quartzite and some other sedimentary rocks belonging to the rest of that period and perhaps a little of the Ordovician. They form an

[1] Figures in heavy type refer to the bibliography at the end of the paper.

escarpment, often very conspicuous, which runs from the southern end of Loch Maree to the north of Loch Eriboll, the members of which are generally "slabby" in structure, composed mainly of quartz, felspar, and mica, though the minute scales of the last appear to have been formed in situ.[1] This group of gneisses was asserted to represent a set of metamorphosed stratified rocks, approximately of Silurian age. Difficulties in this interpretation became graver as the knowledge of petrology increased, till, in the summer of 1882, the problem was finally solved by Professor Lapworth (**12**), who demonstrated that some of the pre-Torridonian crystalline rocks had been carried by overfolding and overthrusting above sedimentaries of later date, and had been greatly crushed in the process. So these "Newer Gneisses" are really Archæan Gneisses, which have undergone pressure-modification, a clastic structure (followed by a certain amount of mineral development, as described above) having been imposed on them at some epoch subsequent to the latest Cambrian and distinctly before the Devonian periods (**13**). A similar origin was claimed by Professor Lehmann in 1884 (**14**) for certain slabby gneisses in Saxony, but in this region the gneiss appears to have been more completely reconstituted, so perhaps the crushing may have occurred at an earlier date, or some local cause have favoured the repairing process.

Rocks of a dioritic or doleritic nature also exhibit a pressure-foliation. The felspathic and ferro-magnesian constituents are crushed, and to a certain extent "rolled out", after which they undergo a process of reconstitution, analogous with that which has been described in the case of granite rocks, but the original augite or hornblende is replaced by an acicular and generally rather smaller form of the latter mineral. The rock becomes, in fact, an actinolitic schist, examples of which are common in the Alps (**15**). The more coarsely crystalline hornblendic gneisses, such as occur in the Lepontine Alps for some distance eastward from the south side of the St. Gotthard Pass (**16**) and in one or two parts of the Tyrol, also afford examples of a coarser form of pressure-foliation.[2]

The bulk of gneisses, especially the banded kinds, were formerly supposed to be metamorphosed sedimentary rocks. That was confidently stated less than half a century ago in textbooks of authority (**17**), and I well remember how often sedimentary rocks were said to pass (i.e. be melted down in situ) into igneous rock (**18**); nay, a metamorphic origin was sometimes attributed even to granite, because, as the specific gravity of its quartz was 2·65, and that of quartz which had been melted was only 2·25, the rock could not have been truly fused.[3] It is now not too much to say that the *onus*

[1] Similar gneissoid rocks occur on the southern border of the Highland complex from near Stonehaven northward for some miles.

[2] Certain minerals, such as hornblende, biotite, chloritoid, ottrelite, dipyr, couseranite, and a plagioclase felspar, seem to form with comparative ease, as will presently be described, in some crushed gneisses and hornblendic rocks.

[3] The advocates of this notion appear to have forgotten that normal crystalline quartz is a frequent constituent of felsites, rhyolites, etc.

probandi lies on anyone who claims a sedimentary origin for a gneiss, whether banded or not, and in the few cases where this can be proved the gneiss is usually limited in thickness and not quite normal in character; sometimes, indeed, the supposed gneiss is found on closer study to be merely a rolled out sill or vein of intrusive granite (**19**). Thus it is prudent, in dealing with gneisses which show no signs of passing, on the one hand, into schists by a gradual transition, on the other into indubitable granites, to carry them for the present to a "suspense account".

I pass on now to those crystalline schists which can be proved to be metamorphosed sedimentary rocks, viz. the group of the quartz-schists, quartz-mica-schists, calc-mica-schists, and crystalline marbles (or dolomites). These sometimes overlie, with marked unconformity, the above-named gneisses, though occasionally it is difficult to divide them. The same may be said of their relation to the overlying hypometamorphic or unmetamorphic strata, but in many cases their division from the one or other is not quite so clear.

The sedimentary origin of these crystalline schists, if we except the *grüner Schiefer* (and we must not exclude the possibility of some of these being metamorphosed tuffs), is unquestionable. In chemical composition they agree with corresponding members of the stratified rocks, and are associated in exactly the same way. Of these associations striking instances may be found in the Val Canaria, Val Piora, on the Nufenen and the Gries Passes, in the neighbourhoods of Binn, Saas, Zermatt, and at sundry localities in the French, Italian, and Austrian Alps (**20**). Here we can find dark or lead-coloured mica-schists, sometimes containing garnets (which may be as large as peas) interbanded with quartz-schists or passing rapidly into calc-mica-schists and marbles. They show the effects, often conspicuously, of subsequent pressure (**21**), but careful study makes it obvious that before this acted they had been well metamorphosed, that change having been due to the joint action of pressure, water, and heat, of which probably the last agent was most above the normal. We infer this from the fact that stratified rocks, which must have been depressed to very considerable depths from the earth's surface, and have been kept for a long time sodden with water, do not exhibit this kind of metamorphism. Its occurrence has often been confidently asserted, but every instance, such as the "fossiliferous schists" of more than one part of the Alps and the "Devonian schists" of the Start district, has broken down, on careful study in the field and with the microscope, like the "Newer Gneisses" of the Highlands.

A quartz-schist consists mainly of grains of quartz, but usually contains small flakes of white or lead-coloured mica, which occasionally form distinct and rather conspicuous bands (**22**). The purer varieties are almost white and slightly slabby (perhaps a superimposed structure. When this schist rests on gneiss its lower part occasionally contains some fragments of felspar and (in a few cases) pebbles of vein quartz or some compact rock resembling a hälleflinta (**23**). Evidently the purer varieties much resemble quartzites, but they present under the microscope a different

structure.[1] The quartzites consist of distinct grains, angular or rounded, cemented together by a secondary deposit of quartz, often in crystalline continuity with the original grain, but those in a quartz-schist are rather more irregular and indefinite in outline, so as to give the matrix a slightly streaky structure and even to suggest the possibility that, like the mica, they are authigenous. The quartz-schists frequently pass up into mica-schists, and in one part of the Val Piora a fairly normal example is associated with a mica-schist containing many rather large staurolites (**24**). In this district masses of very dark mica-schist are abundant, and their lower part is sometimes repeatedly interbanded with a not very pure quartz-schist. Garnets occur in both these rocks, but are more abundant and rather larger in the mica-schist. The same garnet-bearing dark mica-schist occurs at the Alp Vitgira on the Lukmanier Pass (**25**) as well as on the Nufenen Pass (**26**) and in the Binnenthal (**27**). The dark mica-schist in the Val Piora apparently passes locally into calc-mica-schist, and it is found in a ravine on the western side of the Val Canaria, associated with a pale-coloured schist, largely composed of two species of mica, and with a calc-mica-schist, locally passing into a white marble.[2] In fact, these different kinds of schists may be seen to pass one into another, just as sandstones, clays, and limestones do among the ordinary sediments, so there cannot be any doubt that they are the metamorphic representatives of such rocks.

In the Alps the overlying slates and other sedimentary rocks, as a rule, are readily distinguishable from the above described schists, but at one or two localities, authigenous garnets and staurolites have been asserted to occur with belemnites, joints of crinoids, and other fossils, which prove the supposed schists to belong to the Lias (**28**). This assertion finds a merely superficial support from field evidence and breaks down wholly when tested with the microscope. The minerals associated with those organisms and called garnets and staurolites are neither the one nor the other, but only some silicates too impure to be identified with certainty, but probably allied to dipyr and a colourless chloritoid, which, under certain circumstances, form with comparative ease[3] and do not indicate sufficient metamorphic action to obliterate any organism, though this is generally one of the first things to disappear before a marked rise of temperature. Nature has, in fact, been setting traps for the unwary petrologist.

In some localities the apparent passage from a dark crystalline

[1] The pressure-modified quartzites of the Scotch Highlands, such as those of Glendhu in Sutherland, present the nearest resemblance to a true quartz-schist.

[2] Descriptions of these schists, together with analyses quoted from an article by Dr. Grubenmann (Mitth. Thurg. naturf. Ges., Heft viii, 1888), are given in a paper on "Crystalline Schists and their Relation to Mesozoic Rocks in the Lepontine Alps" (Q.J. 1890, pp. 187–236). The garnets appear to be an impure representative of the alumina-lime variety. They are sometimes about one-third of an inch in diameter.

[3] They had already been analysed (see Q.J.G.S. 1890, p. 233) by Fritsch (Beiträge zur Geol. Karte der Schweiz, Lief. xv, p. 127) and the impossibility of identifying his *knoten* and *vrismen* with *garnet* and *staurolite* implicitly demonstrated.

schist to a slate is due to exceptionally severe pressure having locally converted the slate into a phyllite and so far crushed the schist that it is hardly distinguishable from the latter rock. This may be seen, for instance, in the Tyrol on the ascent from Mittersill to Kitzbühel (**29**), and in the cliffs south of Torcross in Devon (**30**).

(To be continued.)

II.—On the Highest Coal-measures or "Zone" of *Anthracomya Phillipsi* in the Durham Coalfield.

By C. T. Trechmann, D.Sc., F.G.S., and D. Woolacott, D.Sc., F.G.S.

(PLATE V.)

IT has been known for some considerable time that the highest beds of the Northumberland and Durham Coalfield lie approximately beneath the town of Sunderland.[1] The great syncline of the Coal-measures of this area is distinctly accentuated in North-East Durham, so that a secondary basin-like depression is formed, in the centre of which these high beds occur.[2] Beneath Sunderland, where the top layers also exist, the Carboniferous rocks are concealed by the overlying Permian strata, but at a place called Claxheugh on the Wear, about two miles west of Sunderland, the Coal-measures are exposed for a short distance on both the north and south banks of the river.

These beds represent the horizon known as the zone of *Anthracomya Phillipsi*. It is not generally known among British geologists that these specially high beds occur in the northern coalfield, so that we consider it desirable to put this fact definitely on record, and to add some details on the stratigraphy and palæontology of the beds in question, the result of several visits to the locality. The section described is exposed on the north bank of the Wear, and is the one that is specially fossiliferous. The shale, with the bands of clay ironstone from which most of the fossils are obtained, does not occur in the section on the opposite side. The small section of Coal-measures, about 90 yards long and about 15 feet high, is cut off by a fault on the west which throws down the Permian Yellow Sands. This is the same displacement that brings down the Permian rocks, which are so well exposed in the Claxheugh escarpment.[3] The Carboniferous rocks consist of argillaceous sandstones at the base, a layer of dark fissile shale, 3 feet thick, with two or three irregular nodular bands of clay ironstone, and beds of grey sandy micaceous shale. The sequence is shown in the section, Fig. 1. During one of our visits to the locality, Dr. Woolacott observed that the exposure, besides the four

[1] J. W. Kirkby, "On the Occurrence of Fossils in the Highest Beds of the Durham Coal-measures": Trans. Tyneside Nat. Field Club, vol. vi, pt. ii, pp. 220–5, 1864.

[2] D. Woolacott, "Stratigraphy and Tectonics of the Permian of Durham (Northern Area)": Proc. Univ. Durham Phil. Soc., vol. iv, pt. v, p. 246, 1911–12.

[3] D. Woolacott, "On Sections in the Lower Permian Rocks at Claxheugh and Down Hill, Co. Durham": Trans. Nat. Hist. Soc. Northumberland, Durham, and Newcastle-upon-Tyne, N.S., vol. v, pt. i, p. 155.

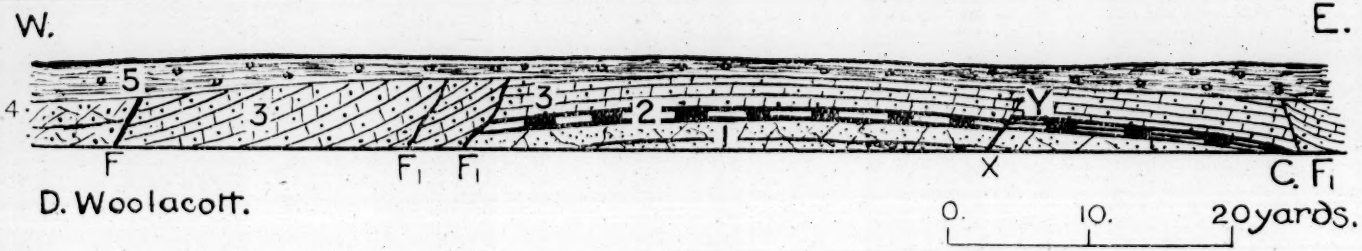


FIG. 1.—SECTION SHOWING POSITION OF FOSSILIFEROUS IRONSTONE BANDS AND THRUST-PLANE. (Drawn by D. Woolacott.)

1. Light-coloured argillaceous sandstone stained yellowish-brown along irregular fractures.
2. Shale (3 feet thick) with ironstone bands, above which is a layer of slickensided clay and ground up and broken shale 1½ in. in thickness. To the west of the small displacement *XY* it is on the top of the shale, but to the east it is continued straight on at the same level in the shale towards *C*, not being faulted by *XY* (see Fig. 2). It is a plane of thrusting.
3. Grey sandy micaceous shale.
4. Yellow Sands (Permian), much fractured.
5. Boulder-clay.

F. Fault throwing the Yellow Sands against the Coal-measures.

F_1. Minor faults.

or five faults that occur in it, includes a peculiar layer, 1½ inches thick, of slickensided, broken up, and powdered shale, which occasionally splits and does not maintain a constant horizon in the shale (see Fig. 2). This disturbed band marks a plane of thrusting, the beds above having moved on the upper layers of the shale, the powdered and broken up material acting as a lubricant. It is impossible to say whether the displacement is of large or small magnitude owing to the faults which cut out the beds, but it seems probable that the movement to which this slickensided layer is due was produced by the same forces that caused the extensive series of horizontal movements, which have been proved to have occurred in both the Coal-measures and the Permian rocks of South-East Northumberland and North-East Durham,[1] the results of which are so well exposed in the Permian rocks of Claxheugh.[2]

These fossiliferous Coal-measures are the highest visible in the northern coalfield. Those situated immediately under Sunderland are inaccessible to research, and any evidence available from borings or pit-sinkings can yield little palæontogical evidence of value, but it can be fairly safely asserted that those that occur in this section cannot be more than 50 or 60 feet below the top of the Coal-measure floor, as it existed just previously to the deposition of the overlying Permian. Also our knowledge of the lie of the coal-bearing rocks beneath the east of Durham enables us to assert that they are near the top of the highest Carboniferous strata, as these occur in Northumberland and Durham. This zone, therefore, is of importance, since it marks the upper limit of the Coal-measures of these two counties.

Evidence bearing upon the height of these beds above the chief workable seams of the district has been obtained from details of the sinkings at Hylton Colliery, which is situated about a quarter of a mile to the east and Monkwearmouth Colliery about 2 miles in the same direction. No intervening faults of any great magnitude occur. At the former colliery the thickness of the Coal-measures to the main coal of the Wear is about 1,300 feet, and to the Maudlin or Bensham seam about 1,375 feet, while at the latter the thickness to the main coal is about 1,170 feet, and to the Maudlin 1,265.

Near the top in the Hylton sinking some bands of clay ironstone are recorded, which may very well be the same as those at Claxheugh, as the beds dip gently in an easterly direction.

Palæontology of the Claxheugh Beds (C. T. T.).

"*Ancylus*" *Vinti*, Kirkby. (Pl. V, Figs. 1–4.)

This problematical fossil occurs in great numbers in the layers of clay ironstone. Generally the specimens are more or less crowded together along certain bands in the rock to the exclusion of other fossils, but occasionally they occur scattered about on the surfaces that yield the bivalves of the group of *Anthracomya Phillipsi*.

[1] The evidence is detailed in "Stratigraphy and Tectonics of the Permian of Durham": op. jam cit., pp. 288–99.

[2] Op. jam cit., p. 159.

One of my specimens measures 2 mm. in length and slightly over 1·5 mm. in height; another is 3 mm. long and 2 mm. high.

Kirkby wisely declined to arrive at any definite decision as to the real nature of this organism and stated clearly his reasons both for and against regarding it as an *Ancylus*, a *Discina*, an *Estheria*, or a bivalve mollusc.

Some later geologists have, however, adopted a less cautious attitude, and Dr. Wheelton Hind has definitely described and figured specimens from Claxheugh as a lamellibranch, calling them *Carbonicola Vinti*.[1] *Carbonicola* is a genus which bears hinge-teeth.

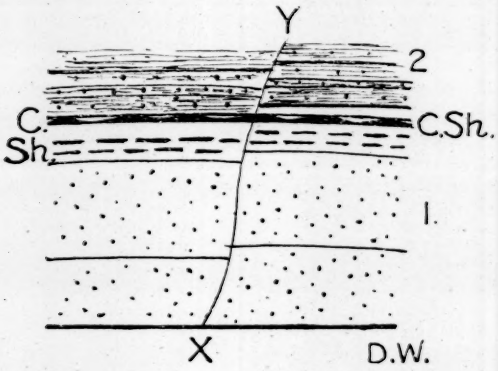


FIG. 2.—SECTION AT *XY* IN FIG. 1. (Enlarged.)

Sh. Shale with fossiliferous ironstone bands, slightly faulted along *XY*; the fault dies out in the upper beds.

C. A band of slickensided clay and broken shale (1½ in. thick), which on the west of the section runs along the top of the ironstone band beneath the sandy shale, but is not faulted by *XY*, being continued straight on in the bed of shale. This layer lies along a thrust-plane.

1. Light-coloured argillaceous sandstone.
2. Thinly bedded sandy micaceous shale.

He regards the Claxheugh specimens as "the closely compressed remains of the periostracum of a large number of shells". My examination of a large series of specimens, however, reveals difficulties in accepting this view. They show no trace of calcareous matter and seem to have consisted entirely of chitinous material, but on the same slab one observes numerous valves of *Anthracomya*, and of small entomostraca still retaining their calcareous nature, so that it is not easy to believe that the valves of "*Carbonicola*" *Vinti* have become decalcified, while those of other equally delicate calcareous organisms have remained unaffected. The Claxheugh specimens are clearly not shells which have been partly decomposed or decalcified.

However, a speaker at the discussion on the above-mentioned paper assumed that the bivalve nature of the fossil was decided. It is clear to me from examination of my specimens that the organism

[1] "On three New Species of Lamellibranchs from the Carboniferous Rocks of Great Britain": Q.J.G.S., vol. lv, p. 365, 1899.

was bivalvular and cannot be either an *Ancylus* or a *Discina*. It seems unfortunate, however, that a shell from the Upper Coal-measures of the North Staffordshire Coalfield, which from the illustration and description seems beyond doubt to be a true and adult form of *Carbonicola*, should have had the specific name of "*Vinti*" attached to it on the assumption that it is identical with the chitinous organism from Claxheugh.

The name has now found its way into Continental publications. E. Haug,[1] speaking of the Coal-measures of Great Britain, says: "The Upper series is characterized by intercalations of beds of *Anthracomya Phillipsi* and *Carbonicola Vinti*, lamellibranchs generally regarded as freshwater forms." Kirkby, as his habit was, gave an accurate description of the organism, and one can add little to his diagnosis, which is as follows: "length one-twelfth to one-eighth of an inch, breadth one-fourteenth to one-tenth, sub-oval or nearly circular, with the posterior margin straight, flatly patelliform, with an eccentric reflexed apex posteriorly placed, shell delicate, surface ornamented with several rather coarse concentric plaits."

I am much indebted to Mr. H. Bolton, M.Sc., F.G.S., to whom I submitted some of the specimens for the suggestion that these organisms are the "spat" of *Anthracomya Phillipsi*. He writes: "I have examined the fossils you sent me, especially the example of '*Ancylus* (*Carbonicola*)' *Vinti*, and have found them of more than usual interest. In the first case I fail to see any *Carbonicola* character at all in any of them: what I do see, is that so far as my experience goes, you are dealing with 'spat' and not with adult forms of mollusca. I gave a long time to the study of the life-history of *Anthracomya Phillipsi*, and had the advantage of a great series of specimens from several coalfields, whilst I had the experience of thirty years to aid me. I feel convinced that your specimens and the *Ancylus* ('*Carbonicola*') *Vinti* are nothing but the spat of *Anthracomya Phillipsi*. As you will see by my paper,[2] I have linked three former species, viz. *Anthracomya lævis* var. *Scotica*; *A. minima*; and *A. Phillipsi*. The first is the 'spat' stage, the second the adult stage, and the third the senile stage of the one species. I shall be interested to learn whether your *Ancylus Vinti* ever occurs away from the *Anthracomya Phillipsi*. Of course it may, but I think you will find the other two species not far off. The 'spat' stage has usually a short straight hinge-line, and the valve is perfectly symmetrical to it and not oblique at all; the obliquity comes in with the '*minima*' stage. Until the latter is reached the central and youngest part of the umbones remains fairly elevated and convex. As the '*minima*' stage increases the new shell matter is added to the ventral-posterior border at a much greater rate than elsewhere, and as a result there is an increasing obliquity, which reaches its maximum in the '*Phillipsi*' stage. I have seen shells so well preserved that you can mark off the three stages on the surface on the one shell."

[1] *Les Périodes Géologiques*, vol. ii, p. 764.

[2] "Fauna and Stratigraphy of the Kent Coalfield": Trans. Inst. Mining Engineers, vol. xlix, pt. iv, p. 33, 1915.

On my inquiring further in this matter Mr. Bolton writes: "With respect to the shell of *A. Vinti*, I think that in the 'spat' stage there was little or no calcification. I would not be sure, but I rather fancy that the shell is little more than a top integument, and may possibly be represented by the periostracum at a later stage. I am assuming this from the Glochidia larva of the common Swan Mussel. I have not seen the latter for some years, but I think the valves are well domed and hooked at one end, so that the larvæ can hang on to the gills of the parent; afterwards calcification takes place in regular concentric layers around the umbonal point, and the hooked condition is left together with the tegumentary-like appearance; and the shell assumes more or less the appearance of the adult stage."

It was, therefore, a matter of interest to me to try and observe whether on any of the Claxheugh specimens one could see the "spat" form in the act of growing into the *A. lævis* form or whether the umbones of the larger shells showed any trace of the wrinkled stage of the spat. I examined all the available specimens with this point in view. Certainly there are no specimens of *Anthracomya* on the slabs of smaller size than "*Ancylus*" *Vinti*, which is a fact in favour of the latter being actually the young stage of the *Anthracomyas* associated with them.

In one or two instances there seemed to be evidence of the wrinkled periostracum of the "spat" stage remaining on the umbo, though in nearly all the specimens after the calcification of the interior of the valves of the spat, the character of the shell seems to change rapidly and the periostracum to disappear. (See Pl. V, Figs. 6 and 7.)

Notwithstanding these difficulties I am quite inclined to agree with Mr. Bolton's interesting suggestion that all the bivalvular organisms in this bed belong to different stages of growth of one and the same shell, commencing with "*Ancylus*" *Vinti* and ending with *Anthracomya Phillipsi*.

One slab shows clear evidence of an "*Ancylus*" *Vinti* with incipient calcified growth-lines developing round the anterior, posterior, and lower margins.

I may here remark that the apex of "*Ancylus*" *Vinti* does not correspond with the beak of the more adult form *Anthracomya minima*. In the former, in well-preserved examples, the rounded and rather indefinite apex never occupies the hinge-line but is situated well below it, and anterior to the middle of the shell, or eccentric, as Kirkby described it.

Anthracomya Phillipsi (Williamson). (Pl. V, Figs. 5–7.)

Bivalves having the appearance of this form occur in great numbers more or less crushed in the two bands of clay-ironstone in the Claxheugh section.

My specimens vary in size from 6 mm. long and 3 mm. high to 32 mm. long and 14 mm. high, and certainly appear to me to represent various stages of growth of one and the same species.

No other bivalves have been found in these beds, consequently the

group of shells appears to mark a definite horizon in the Durham Coalfield.

Not much zonal collecting of the fossils has been done in the Coal-measures of this district, but I have a fair number of bivalves, mostly collected at different times from pitheaps, and the Newcastle Museum also has a number of specimens. From these it is possible to ascertain roughly the sequence of the "mussels" in the main Coal-measures of Durham and Northumberland.

Kirkby, in 1864, mentions the shell that occurs at Claxheugh as *Anthracomya acuta*, a species which is now placed in the genus *Carbonicola*, but he gives no description of it.

I submitted some of the smaller Claxheugh shells to Mr. Bolton who returned them to me labelled "*Anthracomya minima* stage of *A. Phillipsi*", and he remarks in a letter, "I have been breaking up the ironstone nodules you sent and am extremely interested to note that they contain beautiful examples of *A. minima*, the intermediate stage between *A. lævis* var. *scotica* or 'spat' and the adult *A. Phillipsi*."

I am not sufficiently well acquainted with the mollusca of the Coal-measures to be able to discuss whether Mr. Bolton's views on the various growth stages of this shell are in every instance correct or not.

It is also very difficult on reading the various publications on the question to determine whether or not *A. Phillipsi* represents a distinct zone in the English Coal-measures, and its recorded distribution offers some points that require further elucidation.

In the North of England its horizon seems to be a well defined and restricted one. In Yorkshire it is reported, so far as I can ascertain from one locality only,[1] namely, from a cutting near Conisborough, in a band of soft ironstone about two inches thick among clays and sandstones underlying the Permian. In the Nottingham area Messrs. Lamplugh and Gibson[2] say that "the range of the distinctive species of the genus *Anthracomya* has not been definitely fixed but *A. Phillipsi* occurs in the top beds of the middle Coal-measures at Gedling", and Mr. R. D. Vernon informs us that *A. Williamsoni* (Brown) invariably accompanies the roof shales of the "Top Hard Coal".

In the concealed coalfield of Yorkshire and Nottinghamshire its horizon seems also to be a definite one where it has not occurred below the Top Hard or Barnsley Coal, and is regarded as characteristic of the Middle Coal-measures above that seam.[3]

Matters, however, in the South of England, are much less clear and Mr. H. Bolton[4] states that "*Anthracomya Phillipsi* is equally abundant in the lower Coal-measures of the Bristol district and in the upper series of Radstock".

In the Kent Coalfield a similar uncertainty seems to prevail. Mr. Bolton, referring to *Anthracomya lævis*, *A. lævis*, var. *Scotica*,

[1] H. Culpin & G. Grace, *Naturalist*, No. 577, February, 1905, p. 40.
[2] *Geology of Nottingham* (Geol. Surv. Mem.), 1910, p. 17.
[3] Walcot Gibson, Geol. Surv. Mem., 1913, p. 25.
[4] Q.J.G.S., vol. lxvii, No. 267, p. 329, 1913.

A. minima, and *A. Phillipsi*, says they are the dominant fossils of the Kent Coalfield and occur in countless numbers and at many horizons.

The remaining animal fossils at Claxheugh require little notice. On a recent visit I was fortunate to collect in the sandy shales above the clay-ironstone bands a small limuloid crustacean, which Dr. H. Woodward has described as a new species of *Bellinurus* under the name of *B. Trechmanni*.[1] The specimen is now in the British Museum (Natural History).

Insect remains were found here many years ago, but no one has since succeeded in finding any more of them. Kirkby records them as *Etoblattina Mantidioides*, Goldenb.; *Lithomylacris Kirkbyi*, H. Woodw.[2]

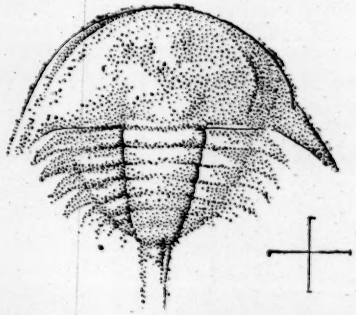


FIG. 3.—*Bellinurus Trechmanni*, H. Woodw., sp. nov. × 4. Upper Coal-measures: Claxheugh on the Wear, Sunderland.

Fish-scales are fairly plentiful. Dr. A. Smith Woodward was kind enough to examine those I collected and reports that they are "Well-preserved specimens of the scales of *Rhizodopsis sauroides* (Williamson)".

Ostracoda are common but have not been examined in recent times. Kirkby recorded the occurrence here of *Beyrichia arcuata*, Bean, and another small entomostracan related to *Cythere* or *Cypris*.

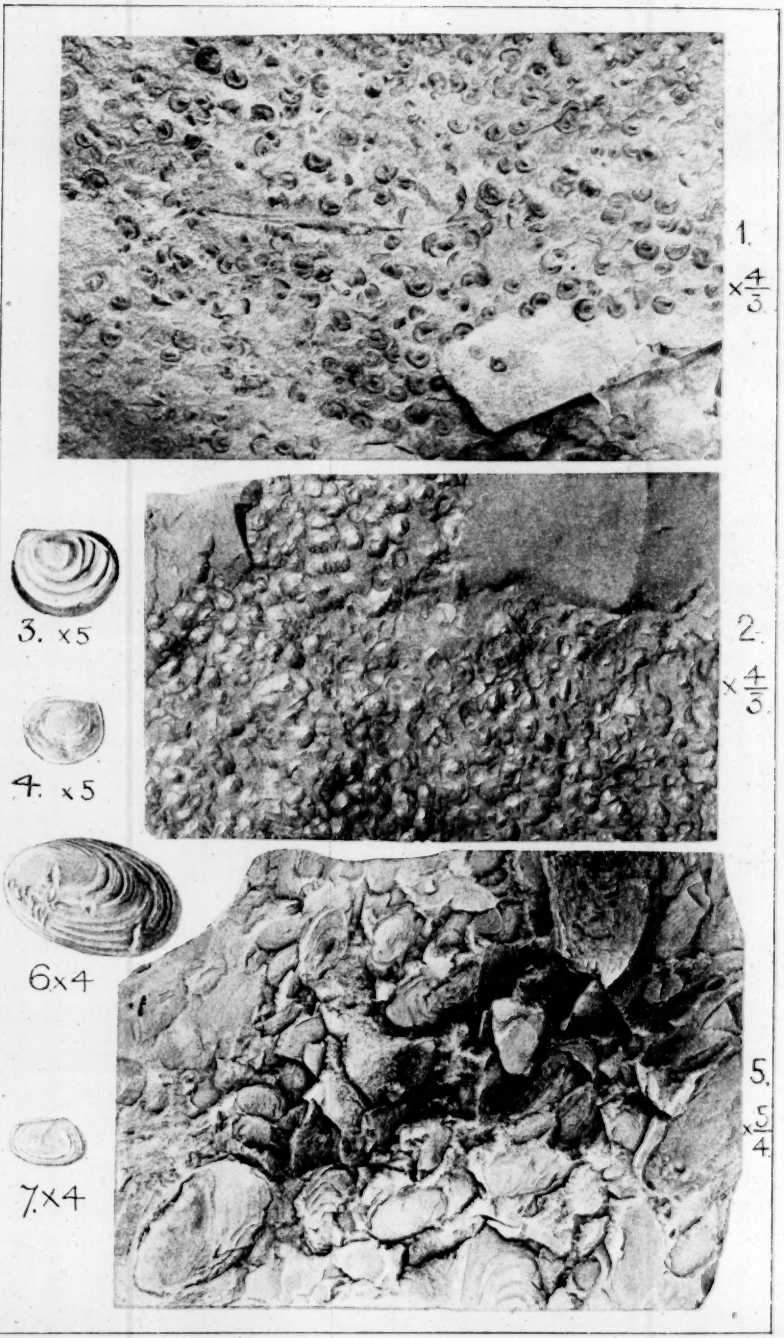
PLANT REMAINS.

Plant remains are rather scarce at Claxheugh, but occur in the ironstone bands. Hoping to obtain some results I kept all the specimens I collected from time to time and have recently sent them to Dr. Kidston, F.R.S., who has very kindly identified them, and has given me the following list of species and the results of his examination of them.

"Those that are sufficiently good for determination are

Neuropteris gigantea, Sternb.
Calamites suckowii, Brongt.
Lepidodendron simile, Kidston.
Lepidophyllum triangulare, Zeiller.
Sigillaria discophora, König sp.

[1] GEOL. MAG., Dec. VI, Vol. V, p. 470, 1918.
[2] GEOL. MAG., Dec. I, Vol. IV, p. 390, Pl. XVII, 1867.



C.T.T. photo. Vale & Sons, imp.

SLABS OF CLAY-IRONSTONE FROM THE HIGHEST COAL-MEASURES, CLAXHEUGH, CO. DURHAM.

"It is difficult, owing to the small number of species collected, to give a definite horizon. There are no specially characteristic species contained, but it is either Westphalian or possibly the Black Band group of the Staffordian series which immediately overlies the Westphalian. There is nothing in the collection to enable one to decide this."

EXPLANATION OF PLATE V.

Slabs of clay-ironstone from the highest Coal-measures at Claxheugh, co. Durham.

FIG. 1.—Surface with a number of individuals of "*Ancylus*" *Vinti*, Kirkby. Supposed to be the "spat" of *Anthracomya Phillipsi* (*fide* Herbert Bolton).

,, 2.—Ditto, the individuals more crowded together.

,, 3.—A specimen of "*Ancylus*" *Vinti*, Kirkby, from slab (Fig. 1). × 5.

,, 4.—Another specimen of same, from same slab. × 5.

,, 5.—Slab covered with lamellibranchs. The largest specimens are *Anthracomya Phillipsi* (Fig. 6); the smaller ones are *A. minima*, Ludwig, the younger stage of *A. Phillipsi*. Some of these have the umbones wrinkled and incompletely calcified, recalling "*Ancylus*" *Vinti*. Specimens of *A. vinti* occur also on this slab.

,, 6.—*Anthracomya Phillipsi*, from slab 5. × 4.

,, 7.—Another younger specimen of same, ditto. × 4.

III.—The Mineral Composition of the Lower Greensand Strata of Eastern England.

By R. H. Rastall, M.A., F.G.S.

IN the year 1913 the author formed the intention of carrying out a comprehensive investigation of the mineral composition of the Lower Greensand strata of England, in order to ascertain whether any definite conclusions could be drawn as to the sources of the material and the geographical conditions that existed while the deposits were being formed. A large number of specimens were collected along the outcrop from the Wash to the borders of Buckinghamshire and examined by the usual laboratory methods. This work was interrupted by the outbreak of war, and on returning to Cambridge after an absence of nearly four years on Government service circumstances proved to be unfavourable to a continuance of the work on the scale originally contemplated. The district already dealt with forms in itself a fairly well-defined unit, and it was decided to publish an account of the results already attained, in the hope that they may be of service to future workers in this interesting field of petrological and stratigraphical research.

Introduction.

The formation generally known as the Lower Greensand attains a considerable development in the eastern midland counties of England. It has an almost continuous outcrop from the shores of the Wash to the western borders of Bedfordshire, but further to the west it is discontinuous and does not appear at the surface over long stretches of country, being overlapped by the Gault. It is a question still undecided whether it was ever deposited continuously in this region and afterwards removed by inter-Cretaceous denudation, or

whether, on the other hand, there were from the beginning gaps in the succession owing to intervening land-areas. At all events, it is certain that the Lower Greensand thinned out towards the south against the high ground of the London Palæozoic plateau, which was first completely submerged in Gault times, as shown by the records of numerous deep borings. The thickness of the Lower Greensand within the district as above defined undergoes certain remarkable and more or less regular variations, and the present author has already put forward reasons for believing that this variation is due to the existence in Lower Cretaceous times of a ridge of land running in a general north-west to south-east direction, parallel to the known strike of the Charnian rocks, and probably due to posthumous movements of an ancient fold-line.[1] Repeated movements of this axis have been clearly demonstrated in other instances by Professor Kendall,[2] although he expressly disclaims any belief in its influence on the Lower Greensand. On that point the present author ventures to maintain his own opinion. It is at any rate a striking fact that the strongly marked diminution in thickness of the Lower Greensand takes place just over the district where it might be expected on this supposition. In the west of Bedfordshire it is 250 feet thick, in Norfolk about 150 feet, whereas at Upware and Ely there are only a very few feet, and it is possible that in places it is absent altogether. These facts can only be accounted for by overlap against a land-surface, apparently an isthmus dividing two seas, which was gradually being submerged and was finally overflowed at the beginning of Upper Cretaceous times, since there is no doubt that the outcrop of the Gault is continuous, although the thickness of this formation diminishes greatly towards the north-east.

The stratigraphy and palæontology of the Lower Greensand present many problems of great interest and difficulty; some of them are still matters of discussion, as, for example, the true age and origin of the so-called "derived" fossils, which are so common in the pebble-beds of some districts. The present author is not competent to deal with this and other cognate matters, nor with the question of the exact correlation of the strata of the midland and eastern counties with those seen elsewhere. The object of the present paper is merely to set forth the results of a mineralogical examination of the sands of certain areas in the hope that the facts ascertained may assist in throwing light on some factors of a larger problem, which must eventually be dealt with by others.

1. Carstone, Hunstanton.

The general character of the rock forming the lower part of the cliff section at Hunstanton is so well known as scarcely to require detailed description. It must suffice here to say that the finer beds consist of a highly ferruginous sand, each grain being coated by a pellicle of iron oxide, and the whole more or less cemented by the same substance. Owing to this circumstance the preparation of the material for minute investigation presents considerable difficulties.

[1] Rastall, *Geology in the Field*, 1909, pp. 140–4.

[2] Kendall, Report Coal Commission, 1905, pt. ix, p. 30.

Even after very prolonged digestion with strong hydrochloric acid it is difficult to get rid of all the brown iron oxide, which clings very closely to the grains, and often forms oolitic structures apparently possessing a skeleton of silica.[1] This sand also contains a good deal more carbonate than those from most other localities, though in this respect it does not approach the calcareous sandstone of the Ely outlier.

When the residue from the preliminary panning, so very necessary in this instance, is digested for a long time with acid, it is found that a large proportion of the separated material consists of brown grains of oxidized glauconite; owing to their low density most of these can be got rid of by shaking and washing in a watch-glass or shallow dish before the bromoform separation. This is an advantage from the point of view of economy of bromoform. Even while the separation in the heavy liquid is in progress it is evident that the average size of the grains that sink is greater than usual, and especially greater than in those specimens from the western and southern areas. This is abundantly confirmed in the microscopic examination of the material, when the difference is very noticeable at the first glance.

Several distinct samples from different horizons in the cliff were separated with the most careful treatment adapted to the special circumstances; all were, however, so closely similar that one general description will suffice. The characteristic minerals are kyanite, staurolite, rutile, zircon, tourmaline, and garnet. The inevitable ilmenite was abundant, and both hornblende and diopside were present in small quantities, as well as an immense number of minute flakes of muscovite.

The crystals of kyanite are abundant and large and as a rule not much rounded, some being quite angular and blade-like; they show clearly the normal extinction angle of 30° and the emergence of a negative bisectrix normal to the principal cleavage, on which the crystals always lie. Staurolite is common in angular chips, much larger than usual, and also in grains of smaller size and more rounded form; it is of the ordinary bright orange colour, with distinct pleochroism. Rutile is abundant in large grains, generally much rounded, varying in colour from a bright orange to a deep blood-red; some show good twin-lamellæ on the common law. Tourmaline is moderately abundant; it is usually in small rounded grains of a greenish or brownish colour, but there are also a few larger and more angular individuals of a greenish-blue; these generally show little crystal form, but possess very sharp angles: they have evidently not travelled very far from their source.

Zircon is very common and it is very difficult to give a comprehensive general description, since it shows so much variation; on the whole, however, it may be said that the great majority of the crystals belong to the granitic type of Krushtchov.[2] They vary much in size,

[1] Phillips, "On the Constitution and History of Grits and Sandstones": Q.J.G.S., vol. xxxvii, p. 17, 1881.

[2] Mem. Acad. Imp. Sci. St. Petersb., ser. VII, vol. xliii, No. 3, 1894; Min. Petr. Mitth., N.S., vol. vii, p. 423, 1886.

some individuals being as much as 0·3 mm. in length, though most are smaller. Many of them show very fine examples of the spherical and tube-like inclusions described by the above-mentioned author. Apart from these the substance is usually quite clear, and zoned and coloured forms are exceedingly rare. The larger crystals are generally quite sharp, but many of the smaller ones are much rounded.

The hornblende is mostly in the form of rounded and rolled grains, or as much rounded as this mineral is capable of becoming owing to its good prismatic cleavage. The colour is greenish blue, with strong pleochroism, and the mineral is undoubtedly a variety rich in soda, approaching arfvedsonite in composition; it may have come from Scandinavia.

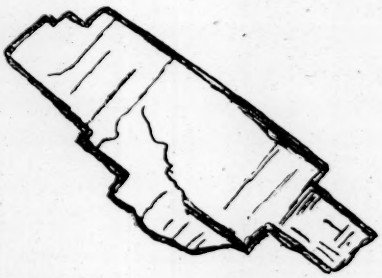


FIG. 1.—Kyanite, Sandringham Sands. × 60.

The most interesting feature of these specimens is the presence of a considerable amount of garnet, a mineral conspicuously absent from most localities. It occurs both in angular chips and in well-rounded grains, the former being distinctly the larger, and includes both brownish-pink and colourless varieties. The significance of the occurrence of garnet in Norfolk will be dealt with later.

2. SANDRINGHAM SANDS, CASTLE RISING, NORFOLK.

These specimens were taken some years ago from a sand-pit near Castle Rising, on the west side of the high road from Kings Lynn to Hunstanton. The sand, which is quite loose and incoherent, is pale grey in colour, evidently containing very little iron. A considerable amount of black carbonaceous vegetable material, probably decayed roots, is present. A slide of heavy materials prepared from this sample (No. 10641 in the Sedgwick Museum Collection) was figured by Dr. Hatch and the present author.[1]

The slide has been again carefully examined. The principal minerals found were kyanite, tourmaline, staurolite, rutile, with a small proportion of zircon and green biotite. The characteristic and dominant minerals are kyanite and tourmaline, which are both unusually large and well developed.

[1] Hatch & Rastall, *The Petrology of the Sedimentary Rocks*, London, 1913, p. 44, fig. 5.

The kyanite occurs in prisms, blades, and shapeless grains, the majority being very little rounded, while some are of very peculiar forms, with conspicuous re-entrant angles (Fig. 1).

Tourmaline shows much variation in size, shape, and colour. It is mostly in good crystals of the usual prismatic forms with flat rhombohedral terminal faces; the edges are, as a rule, only slightly rounded, if at all. The ordinary well-rounded drop-like forms are much less common. The commonest colour is a brownish green, with resinous lustre; a few crystals are pure brown. Some more remarkable grains show a brilliant blue colour at the maximum absorption with one nicol prism, while one in particular shows strong pink and blue tints. This is very uncommon.

Staurolite is as usual in shapeless yellow fragments, nearly always angular in form, a few only showing traces of crystal-faces. Apart from their unusually large average size there is nothing remarkable about them. Rutile, which is not very common, forms red and orange prisms and grains, small and much worn. A few rounded flakes of green mica are a rather unusual constituent. Zircon is rather rare, only a few comparatively large crystals being seen. The other constituents noted in this specimen are, besides ilmenite, brown, yellow, and red opaque grains, presumably consisting of some oxide of iron; the treatment with acid seems to have been rather incomplete, as compared with specimens of later date, treated by standardized methods.

Other slides prepared more recently from material from the same pit showed all the minerals mentioned above, with in addition a few crystals of dark-green and bluish hornblende, and colourless and pale-green pyroxene, together with flakes of muscovite.

One specimen is specially interesting, since it contains a considerable number of rather large grains of garnet, varying from colourless to brownish pink, some being much rounded, while others are very sharply angular and of remarkable forms. These angular chips of garnet are characteristic of many sands of later geological date in the east of England,[1] though it would be hazardous to assume that these were derived from the Sandringham Sands or Carstone.

One sample from this locality was sufficiently clean and free from iron to be separated and mounted without any preliminary treatment by acid. The chief object of this special examination was to determine the presence or otherwise of minerals soluble in acid, such as might be missed in the ordinary ferruginous samples. This specimen yielded some interesting minerals. Tourmaline was remarkably abundant, most of the grains being brown in colour, but a few were bright blue and one of a clear rose-red. The grains are partly of the usual rounded type, but some are sharply angular, suggesting recent derivation from the parent rock at no great distance. Kyanite and staurolite are common and show nothing unusual; zircon is rather rare, while rutile occurs frequently both as the usual shapeless bright red grains and as clear prisms with

[1] Rastall, "The Mineral Composition of some Cambridgeshire Sands and Gravels": Proc. Camb. Phil. Soc., vol. xvii, pp. 136, 138, etc.

lamellar twinning: these are of a very deep red colour. Bluish-green hornblende and various pyroxenes, probably including both rhombic and monoclinic varieties, are frequent. Only one undoubted crystal of apatite was found: this is of the usual prismatic form, showing high refractive index, weak birefringence, straight extinction, and negative optical character. The surface shows the usual speckled appearance of this mineral. The presence of several other minerals was suspected though not definitely proved, including anatase, sillimanite, and barytes. Only one crystal of each was seen, and the determinations could not in any case be made with certainty. The horse-shoe magnet extracted nothing from this sample, so that magnetite is absent and even ilmenite is by no means abundant. No garnet was found.

When compared with specimens from localities to the west of Cambridge all these samples from Castle Rising are notable for the much larger size of the heavy mineral grains, which also show more pronounced angularity.

3. Ely.

The Lower Greensand covers a considerable area around the city of Ely, forming the capping of the higher ground of the "island". The beds are certainly very thin, perhaps not more than 9 or 10 feet, although it is not certain that this is the whole original thickness, since part may have been removed by recent denudation. For the most part they consist of a rather ferruginous sandstone or pebbly grit, which in places become conglomeratic. This is the general character of the rock as used for building stone around the cathedral and elsewhere.

The specimens selected for examination came from the well-known exposure in Roswell Pit. This particular band is in a highly inclined position and has certainly slipped. It is in places a good deal weathered and decomposed to soft and crumbly sandstone, but the fresher portions form an unusually good example of a calcareous sandstone, with a cement of crystalline calcite.

A sample of the soft weathered sandstone, when broken up and washed, is found to consist of fairly large and rather angular grains of quartz, with a large number of grains or small pebbles of ferruginous and cherty rocks, lydianite and other allied types. The quartz grains are estimated roughly to constitute about one-half of the total.

The heavy minerals in separated samples do not show a great amount of variety, but there are one or two special points of some interest. The characteristic, and in fact almost the only, constituents are zircon, tourmaline, kyanite, and staurolite, with a smaller amount of rutile. The zircon crystals, which are the most abundant mineral, present no features of any special interest, beyond the fact that most of them are broken: doubly terminated crystals are very rare. Tourmaline is common, the larger crystals being usually bluish, while the smaller ones are brownish or olive-green and much more rounded. Kyanite is quite abundant, both as large angular flakes and as smaller and more rounded grains. Staurolite also occurs

in the usual small angular chips and fragments, which are common, while larger grains are less frequent. Rutile includes the usual deep red prisms as well as orange and brownish varieties. The most interesting feature, however, is the presence of garnet and blue amphibole in exceedingly small quantity: in fact, the typical sample contained only one grain of each. In their characteristic features, shape, size, and degree of rounding these exactly resembled crystals from the sands of Hunstanton and West Norfolk. The significance of this fact will be dealt with later.

4. Great Gransden.

This interesting exposure is somewhat difficult to find, as it is situated in a small orchard behind a cottage in the straggling village of Great Gransden, some 3 miles N.E. of Gamlingay. The orchard is really an old quarry, but most of it is now overgrown. On one side, however, the rock is well exposed and appears to show a very sharp dip of some 40°. It is clear, however, that this is in reality current-bedding.[1]

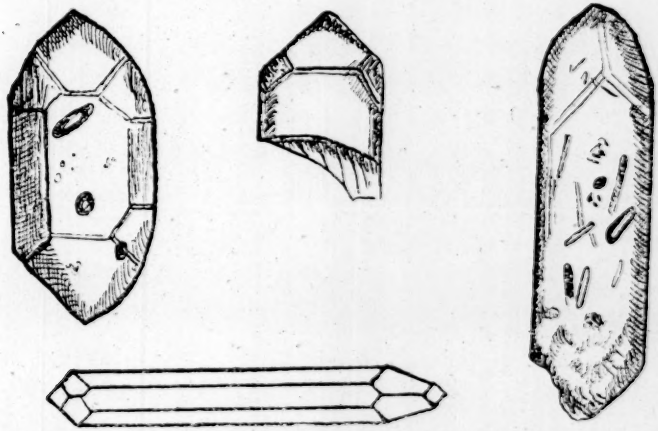


Fig. 2.—Zircons, Great Gransden. × 200.

The rock here is of a yellowish colour, and rather coarse in texture, some layers being almost conglomeratic, with small and well-rounded pebbles of quartz, chert, and lydian-stone. There is nothing remarkable about these or about the lighter portion of the finer constituents, but the heavy minerals after separation are interesting, and as might perhaps be expected from the generally coarse texture of the rock, they are of fairly large size. In particular, some of the staurolites reach a diameter of 0·5 mm.

The most abundant mineral is zircon in numerous varieties, to be hereafter described, while rutile is also very common. Staurolite, though in large pieces, is not very abundant, and the same remark

[1] Fearnsides, *Natural History of Cambridgeshire* (Brit. Assoc. Handbook), Cambridge, 1904, p. 22.

applies to tourmaline. Muscovite is common in small flakes. Among the rarities may be mentioned a very few crystals of orange sphene, a few bits of colourless pyroxene, and a single very angular colourless isotropic fragment, apparently garnet. A large pale-orange flake with slight pleochroism, distinct striations, and straight extinction, is doubtfully identified as brookite, but it may be an unusual form of rutile. A black metallic-looking mineral in prismatic crystals is ilmenite.

Zircon is remarkably abundant and shows a great variety of forms. Nearly all the types described by Krushtchov may be recognized, together with a good many intermediate forms. The commonest habit appears to be the square prism with pyramidal terminations, 100, 111, while similar prisms with their edges bevelled by narrow 110 faces are also abundant. In many cases the angle made by the edges of the pinakoid or prism and pyramid can be measured with sufficient accuracy to determine the form. The horizontal edge

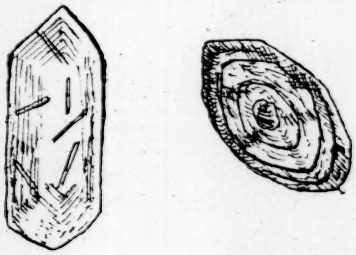


FIG. 3.—Zoned Crystals of Zircon, Great Gransden. × 200.

made by the intersection of 110 and 111 is very rare here, though common elsewhere. Another common type is the square prism terminated by the bipyramid 311, the gneissic type of Krushtchov. One very remarkable crystal showed a very long prism with 100 and 110, the terminations being different at the two ends. At one end 311 is dominant, while the other appears to show a simple pyramid (Fig. 2). However, in these very small crystals with high refractive index, it is difficult to be certain of the forms, owing to the strong internal reflection and the rounding of the edges and corners. Pale-pink and pale-brown crystals, often much rounded and with strongly developed zonary structure, are also very common. According to the latest researches these may be xenotime, which appears to be isomorphous with zircon and even to form parallel and alternating intergrowths with it. These zoned crystals are on the whole more rounded than those without zonary structure. Fig. 2 shows a number of sketches of interesting forms, some with conspicuous inclusions of various kinds, including both crystals and spherical or spheroidal bodies, which Krushtchov believes to be glass, while Fig. 3 shows zoned crystals of zircon or xenotime, one of them being very much rounded by attrition.

This specimen also contains several interesting forms of rutile, especially those showing twin-lamellæ. The colour of the crystals of this mineral varies from yellow to orange-brown and deep red. One conspicuous elbow twin on the common 101 law is of a quite pale yellow colour, but most are darker than this. Fig. 4*a* shows a deep-red, rounded crystal with twin-lamellæ making an angle of 61° with the prism zone, while Fig. 4*b* shows a remarkable resemblance to a crystal figured by Dr. Teall from the Bagshot Sands of Hampstead Heath.[1] The arrow-head twins there figured have, however, not been observed in the Greensand. It is clear that rutile varies very widely in many of its physical characters, especially in colour and crystallographic development, and its discrimination from the other TiO_2 minerals is not always easy, especially in the case of brookite. The latter mineral, however, does not appear to form twins, which are so common and characteristic in rutile.

The other minerals from this locality do not show any noteworthy features.

5. Gamlingay.

A few years ago the large brick pit at Gamlingay afforded a very good section showing the unconformity of the Lower Greensand on the Ampthill Clay, but it is now a good deal overgrown and obscured. The sands are somewhat ferruginous, fine, and very uniform in texture, without pebble-beds.

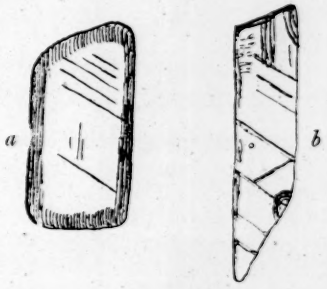


Fig. 4.—Crystals of Rutile, Great Gransden. × 200.

From an examination of washed but unseparated samples it is clear that heavy minerals are unusually abundant here, since specimens mounted without any concentration show a large number of grains of most of the characteristic species. In samples from most other localities it is rare to find more than half a dozen grains in any one slide. The quartz grains vary much in size and shape: some are quite angular, but the majority are more or less rounded, while a few are very round indeed. The characteristic heavy minerals in separated samples are zircon, kyanite, staurolite, tourmaline, and rutile.

Zircon is found in many varieties; some are fairly large, having the form of long prisms with the usual inclusions, but the majority

[1] Teall, *British Petrography*, London, 1888, pl. xliv, fig. 4.

are rather short and stumpy. Some pinkish zoned crystals enclose what appear to be prisms of rutile. The smaller zircons are generally very well rounded. Staurolite is generally seen as small angular pieces, but a few rather larger grains show well-marked striations, probably due to cleavage. Rutile is common, the orange-red variety being the more abundant in rather irregular but often well-rounded grains. Tourmaline is less frequent than usual, chiefly as the olive-green variety; one large piece is of a curious brick-red colour. The kyanite is quite normal; there are a few large prisms, but most are rather small, and some unusually well rounded. Pale-green pyroxene is rare, and no other transparent minerals were identified. Ilmenite is abundant in the usual brilliant black or metallic grains. A prolonged search did not lead to the detection of either garnet or sphene.

(*To be continued.*)

IV.—Notes on Ammonites.

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V.

As an illustration of the difficulties encountered in basing the classification on some peculiarity of the Ammonoid suture-line the case of the two families Macroscaphitinæ and Crioceratinæ may again be referred to, the former of lytoceratid, the latter of hoplitid origin. Distinction between these two families was based on the bifid or trifid characters of the first lateral lobe. *Hamulina nitida*, v. Koenen,[1] which shows very nearly equal-sized suture elements, has the trifid first lateral lobe of the type-species of *Hamulina*, namely *H. dissimilis*, d'Orbigny, but the plain shell of the lytoceratid *Anahamulina*. Hyatt[2] put the latter into his family Macroscaphitidæ, but the former, and also the clearly lytoceratid *Pictetia*, into Ancyloceratidæ, i.e. even into a different sub-order.[3] But *Anahamulina subcylindrica*, d'Orbigny, sp., i.e. the type-species itself, has a nearly trifid first lateral lobe, though it is connected through *A. Lorioli*, Uhlig, sp. (with a sub-bifid first lateral lobe), with typically lytoceratid forms. In ornament and coiling also *Hamulina* resembles certain lytoceratid forms (compare e.g. the various forms of Macroscaphitinæ figured by Uhlig[4]).

Sarasin and Schöndelmayer[5] wrote in this connexion: "After having believed, for a moment, that the similarities shown by the

[1] Op. cit., p. 396, pl. lii, figs. 3–5.

[2] In Zittel-Eastman, *Textbook of Palæontology*, vol. i, pp. 371, 588.

[3] The inclusion in Macroscaphitinæ again of *Hamulina*, withdrawal of *Anahamulina*, the inclusion of *Spiroceras* in Crioceratinæ, and many other alterations introduced by Professor J. P. Smith in the chapter on Ammonoidea in the second edition of Zittel-Eastman's *Textbook of Palæontology* (1913), and evidently not based on additional research, cannot be considered improvements on Hyatt's classification.

[4] "Cephalop.-Fauna d. Wirnsdorfer Schichten": Denkschr. d. Math.-Naturw. Cl. d. k. Akad. d. Wiss., vol. xlvi, Vienna, 1883.

[5] "Etude Monogr. d. Ammon. du Crét. Infér. de Chatel-Saint-Denis," pt. ii: Mém. Soc. Pal. Suisse, vol. xxix, p. 154, 1902.

suture-lines of *Hamulina* and *Crioceras* might indicate a real relationship between these two genera, we have convinced ourselves that we have here a simple case of convergence. The first lateral lobe, which at first sight appears to be trifid in certain forms of *Hamulina*, is in reality a bifid lobe, deformed by the reduction of its internal branch." The writer is inclined to doubt, however, whether many of the apparently lytoceratid forms described as "*Crioceras*" by Sarasin and Schöndelmayer "enter into the great family of Perisphinctidæ".

Here the adult suture-line alone has been utilized and the result is far from satisfactory, but even where the ontogenetic development has been worked out, one special peculiarity of the suture-line cannot always be regarded as proof of even generic affinity. The writer has shown[1] that, e.g., in *Psiloceras* and *Tragophylloceras* the external saddle has throughout ontogeny a monophyllic ending, whereas in *Rhacophyllites stella* there are two terminal leaflets. It was assumed, therefore, that *Tragophylloceras* was more nearly related to *Psiloceras* and what were grouped as Pleuracanthitidæ[2] than to the contemporaneous *Rhacophyllites*. Apart from the wide separation, geologically, of *Tragophylloceras* from the Hettangian genera, the fact that not all "*Rhacophyllites*" have a diphyllic external saddle, and the comparative insignificance of these differences in the endings of the external saddle, make it probable that *Tragophylloceras* must be derived from its Mediterranean Rhacophyllitid contemporaries. On the other hand, the phylloid character of the suture-line shows that these genera as well as *Psiloceras* are descendants of the great family Phylloceratida, though few families offer such a striking characteristic of the suture-line for classificatory purposes.

The variability of the symmetrical or asymmetrical arrangement of the folioles of the lobes and saddles is well illustrated in the sutural development of *Polymorphites* cf. *jupiter* given by A. E. Trueman[3] and also in that of *Cymbites globosus*, reproduced from Branco for comparison.[4] In the former the external saddle of stage *h* is trifid on one side and bifid on the opposite half of the same suture-line. Similarly the first lateral lobe is unequally developed on the two sides. In *Cymbites globosus* the first lateral lobe is bifid at first and trifid afterwards, whereas the reverse is the case with the external saddle. Also the first lateral saddle of the last stage and especially the second lateral saddle are not monophyllic like the external saddle of the earlier stage, and therefore do not repeat the progressive complication of the saddles in the manner shown by *Tragophylloceras Loscombi*.

But these two sutural developments are instructive from another point of view. The very deep ventral lobe of *Cymbites* from the third suture onwards shows this genus to be an Arietid, and

[1] "The Development of *Tragophylloceras Loscombi*": Q.J.G.S., vol. lxx, 1914.

[2] The family Pleuracanthitidæ, Hyatt em. Diener, provisionally accepted in the paper mentioned above, cannot be upheld.

[3] Op. cit. (GEOL. MAG., 1917), p. 445, Fig. 10.

[4] Loc. cit., p. 447, Fig. 13.

geological occurrence and general resemblance suggest, at least for the *lævigatus* group, to which the genus *Cymbites* should be restricted,[1] modification of an *Agassiceras* development. On the loss of the typical Arietid venter the first lateral lobe tends to assume larger proportions, just as in *Oxynoticeras* the Arietid suture-line shows an enlarged first lateral lobe and first lateral saddle in compensation for a wide lateral area. *Polymorphites*, on the other hand, has the first lateral saddle indicated already in the second suture, and though in the later suture-lines, owing to carination and the swinging forward of the umbilical portion, which has been shown to occur similarly, with time, in a number of stocks, the first lateral lobe is smaller than the ventral lobe, the tendency here is in an opposite direction, suggesting a round-ventered, Deroceratid ancestor.

Even in cases where the suture-line development has been worked out in detail, widely antagonistic explanations of the affinity of the Ammonites can thus be given. Apart from the striking disagreement shown in the classifications of Ammonoids hitherto proposed, there is also the extraordinary increase in the number of genera created in some of these and adding to the difficulties of the student, and it is not surprising perhaps that none of these classifications has found universal adoption. To give an illustration of the divergence of opinion, the four genera *Grammoceras*, *Hudlestonia*, *Dumortieria*, and *Hammatoceras*, from the *jurense* zone of the Upper Lias, may be taken. Hyatt[2] puts the first and the third into the family Hildoceratidæ, and the others into Pœcilomorphidæ and Phymatoidæ respectively. These three families again belong, according to this author, to two super-families, Arietida (the first two) and Phymatoida. Mr. Buckman,[3] on the other hand, puts these same four genera into four families, and only one genus, *Grammoceras*, is in the same family to which Hyatt had assigned it, i.e. Hildoceratidæ. The remarkable part about these four genera, however, is that they are all, and the first three of them closely, allied. This is almost a return to the classifications of the older authors, for, e.g., Pictet[4] in 1854 grouped *Ammonites radians*, *levesquei*, and *insignis* together in "Falciferi". It is not intended to suggest that these old divisions represent natural groups; but the example tends to show that the scepticism of most general palæontologists towards the modern classifications of Ammonites was not unfounded.

A more permanent and uniform classification of Ammonoids may appear desirable to the general palæontologist and collector who are interested in seeing cleared up the generic nomenclature which, apparently, has drifted into a state of hopeless confusion. But to the stratigrapher it may still seem of little consequence whether a form

[1] Certain aberrant forms, occurring e.g. in the *marmorea* and *margaritatus* zones, and resembling the *globosus-lævigatus* group superficially, cannot be included in the genus *Cymbites*, which is confined to the *Birchi-obtusus* zones.

[2] In Zittel-Eastman, vol. i, pp. 576–7, 1900.

[3] "On the Grouping of some Divisions of so-called 'Jurassic' Time": Q.J.G.S., vol. liv, pp. 442–62; also in *A Monograph of the Ammonites of the "Inferior Oolite Series"*, Supplement, Pal. Soc., vols. 1898–1907, p. cxcviii.

[4] *Traité de Paléontologie*, vol. ii, p. 673.

is referred to the old genera "*Goniatites*" or "*Ammonites*", or to a modern small subdivision. For stratigraphical purposes a much more exact definition than in the past of the horizon of each form will be necessary. Here, again, clearness and uniformity of nomenclature, facilitated by a natural classification, would be of great advantage. Since Mr. Lang[1] has shown that in the case of *Deroceras armatum*, at least at Charmouth, there probably is "an example of the zonal fossil lying entirely outside the zone that bears its name", it will be admitted that this revision of the horizons of Ammonites is of importance. Moreover, little value now is placed on specific identifications for zoning purposes. With regard to graptolites, Dr. Elles[2] wrote recently: "Detailed knowledge of the different species is in no way necessary for the recognition of the different horizons. The nature and value of a Graptolitic zone depends on the assemblage of characteristic forms." And with regard to Ammonites, Mr. Buckman[3] had stated five years previously that "one did not ascertain the date of a deposit so much by the actual species as by the general facies, in the case of Ammonites. Coarse-ribbed *Dumortieriæ*, fine-ribbed *Dumortieriæ*, Ammonites of *aalensis* pattern, Opalinoids, showed the dates as well as more exact identifications, because the successive Ammonites of different genera assumed certain developmental facies".

As important as a revision of nomenclature and horizons seems, to the writer, to be the elucidation of the phylogenetic problems presented by the Ammonites, and the consideration of their evolutionary significance in relation to research done in other branches of modern science. Developmental palæontological research has taken an active part in the establishment of modern evolutionary theories, and with Waagen and Blake[4] one may consider "to have here the true basis of palæontology as an independent science". As Zittel[5] stated: "The character of palæontological literature has been correspondingly modified; the purely stratigraphical treatment of palæontological results has been held more and more distinct from the biological systematic treatment, and the latter places the genealogical direction of research more and more in the foreground."

Since the Ammonite animal is unknown, many important factors of evolution can only be imperfectly inferred and not demonstrated by those structures that alone are preserved to us. The writer would favour, for the fossil forms of Cephalopoda, the division into three main orders, without reference to gills. The Nautiloidea and Belemnoidea are outside the scope of the present paper; with regard to the Ammonoidea, the division into "Ammonitidæ" and "Goniatitidæ" is, of course, as little justified as was the original

[1] "The Geology of the Charmouth Cliffs, Beach, and Fore-shore": Proc. Geol. Assoc., vol. xxv, p. 321, 1914.

[2] Proc. Geol. Assoc., vol. xxvi, p. 267, 1915.

[3] "Certain Jurassic [Lias–Oolitic] Strata of South Dorset, and their Correlation": Q.J.G.S., vol. lxvi, p. 53, 1910.

[4] "The Evolution and Classification of the Cephalopoda, an Account of Recent Advances": Proc. Geol. Assoc., vol. xii, p. 278, 1892.

[5] *History of Geology and Palæontology*, London, 1901, p. 380.

grouping by von Buch into the three sections of Goniatites, Ceratites, and Ammonites, or, by Wright, into three corresponding families. As the discovery of rich Triassic faunæ showed the impossibility of separating the Ceratites from the Ammonites, so the interesting Permian forms dealt the death-stroke to the division into Ammonitids and Goniatitids. Professor Haug[1] stated already in 1894 that "a classification of Ammonoidea into Goniatites and Ammonitids, or into Retrosiphonates and Prosiphonates, would not be really natural, except if all were descended from a single Goniatite family. Permian Ammonites showed, however, that several families were evolved, more or less in a parallel manner, and passed through the Goniatite into the Ammonite stage". Thus, complication of the suture-line, change of the protoconch from latisellate to angustisellate, and modification of the septal necks took place in the different stocks of "Goniatites" that persisted into the Permian and Triassic periods, at different times; and since it is possible that the Goniatites themselves did not originate from one single Nautiloid stock (for in the Devonian several very distinct groups can be recognized) it is clear that the subdivision of Ammonoidea into Goniatites and Ammonitids cannot be upheld.

Haug, in his admirable textbook,[2] indeed, divides the Ammonoidea from the Devonian onwards into several great "phyla": Anarcestidæ and Glyphioceratidæ (the latter with many Triassic families), Agoniatitidæ, Prolecanitidæ (with Ceratitidæ), and Gephyroceratidæ. This last "phylum" includes the Phylloceratidæ and is therefore the root-stock of the host of the Jurassic and Cretaceous Ammonites. The writer[3] had to differ from Haug on this latter point and also from that author's interpretation of the genera *Nomismoceras*, *Dimorphoceras*, and *Thalassoceras*,[4] and there can be no doubt that a good deal of research is necessary yet before this classification of Haug's can be said to rest on a secure foundation; but it marks a splendid advance in the right direction. The same cannot be said for the three "phyla" Belocerata, Tomocerata, and Gephyrocerata, proposed in his work on the Triassic of Albania by G. v. Arthaber.[5] These "phyla", widely separated already in the Devonian, are "assemblages of heterogeneous elements", as Diener[6] has already pointed out, and show the greater value, for classification of the larger groups, of the suture-line compared with other characters.

The Liassic and later families of Ammonites are then looked upon, not as being subordinate to a sub-order "Ammonitidæ" of the order Ammonoidea, but as being, with some Triassic groups,

[1] "Les Ammonites du Permien et du Trias": Bull. Soc. Géol. France, ser. III, vol. xxii, p. 386.

[2] *Traité de Géologie*, vol. ii, fasc. 1, 2, Paris, 1908–11.

[3] Op. cit., 1914, p. 353.

[4] Op. cit., vol. ii, fasc. 1, pp. 754–5.

[5] Beitr. z. Geol. u. Palaeont. v. Oesterr.-Ung., etc., vol. xxiv, 1911.

[6] *Triassic Faunæ of Kashmir* (Mem. Geol. Surv. India), N.S., vol. v, i, p. 3, 1913.

subordinate to the super-family Phylloceratida, which, like the earlier and probably ancestral super-family Glyphioceratida, belongs to some great "phylum" ranging up from the Devonian. These four or five stocks or "phyla", of which one at least begins already in the Silurian, and only one of which transgresses the Trias–Jura border, comprise for convenience the order Ammonoidea.

In tracing these "phyla", based so far mainly on the adult suture-line, stress will have to be laid on the ontogenetic development, as has already been pointed out. Branco,[1] as far back as 1879–80, had dissected sixty-four species of Ammonites; but with a few exceptions, among which Professor J. Perrin Smith's paper on the "Development of *Lytoceras* and *Phylloceras*" [2] may be mentioned, observations on the less obvious features such as the earliest chambers and the gradual development of the various characters, were neglected by palæontologists. When Michaelski in 1890,[3] relying on the differences in the ornament of the inner whorls of the various species of so-called *Virgati*, separated these into the two genera *Oloostephanus* and *Perisphinctes*, he met with opposition, at first, even from A. Pavlow,[4] who wrote, "The older specimens have absolutely the same type of suture and are so much alike in shape and ornament that it is extremely difficult to distinguish them if the ontogenetic development of each cannot be studied." Since then, practically on differences in shape and ornament of the adult shell alone, some twenty new genera have been created for various forms formerly included in *Perisphinctes*, but the ontogenetic development of most of them is still unknown. The writer's personal research has been connected chiefly with Lias Ammonites, and the study of the ontogeny of most of their principal types has now been concluded. The phylogenetic conclusions arrived at differ considerably from the interpretations of the relationship of these Ammonites given by other authors, and prove that until the development of the more important types at least of other periods as well has been studied in detail, there seems little hope of arriving at a satisfactory classification of Ammonoidea.

In conclusion, the writer would like to express his obligation to all those who have helped him with material for research or with valuable suggestions. His thanks are especially due to Dr. A. Smith Woodward, the late Mr. G. C. Crick, and Dr. W. D. Lang, of the British Museum (Nat. Hist.); also to Dr. Wyatt Wingrave, Dr. A. Morley Davies, and Mr. C. P. Chatwin.

[1] "Beitr. z. Entwicklungsgeschichte der Fossilen Cephalopoden": Palæontographica, vol. xxvi, pts. i, ii, 1879.

[2] Proc. Calif. Acad. Sci. [3], i, 1898.

[3] "Die Ammoniten der Unt. Wolga-Stufe": Mém. du Comité Géol. St. Pétersbourg, vol. viii, No. 2.

[4] In Pavlow & Lamplugh, *Argiles de Speeton*, etc., Moscow, 1892, p. 114.

V.—Some Recent American Petrological Literature.

(*Continued from p. 179.*)

"The Igneous Geology of Carrizo Mountain, Arizona," by W. B. Emery. Amer. Journ. Sci., vol. xlii, pp. 349–63, 1916.

This region includes various intrusive bodies: sheets, sills, dykes, and a large laccolith of diorite-porphyry. The presence of six volcanic plugs also indicates extrusion, though all flows have been removed by erosion.

"Contributions to the Geology of Java and Celebes," by J. P. Iddings and E. W. Morley. Journ. Geol., vol. xxiii, pp. 231–45, 1915.

The rocks from Java described in this paper include leucite-tephrite, leucitophyre, shoshonite, basalt, and varieties related to kentallenite and borolanite. Those from Celebes comprise nepheline-syenite, kentallenite, trachyte, and marosite. Full petrographical descriptions and analyses are given.

"Contributions to Sardinian Petrography. I. The Rocks of Monte Ferru," by H. S. Washington. Amer. Journ. Sci., vol. xxxix, pp. 513–29, 1915.

A detailed petrographical description, with analyses, of certain trachytes, phonolites, basalts, and analcite basalts from this well-known locality.

"Primary Analcite of the Crow's Nest Volcanics," by J. D. Mackenzie. Amer. Journ. Sci., vol. xxxix, pp. 571–4, 1915.

A reply to criticisms on some previously published work, the point at issue being as to whether the analcite is primary, or formed by alteration of leucite by sodium solutions in salt lakes.

"Relation of Ore Deposits to different types of Intrusive Bodies in Utah," by B. S. Butler. Econ. Geol., vol. x, pp. 101–22, 1915.

The ore deposits associated with laccoliths and more deeply truncated stocks are of little commercial importance, while those connected with apically truncated stocks are of great value. This is attributed to the concentration of mobile metal-bearing vapours or solutions near the apex of the stocks, in which differentiation was more complete than in the laccoliths. In the case of the more deeply truncated stocks the metalliferous portion has been removed by erosion.

"The Ternary System MgO–Al_2O_3–SiO_2," by G. A. Rankin and H. E. Merwin. Amer. Journ. Sci., vol. xlv, pp. 301–25, 1918.

The temperature-concentration relations of crystalline phases in equilibrium with liquid are discussed and represented by diagrams and a model. A ternary compound, $2MgO.2Al_2O_3.5SiO_2$, was found in two forms with a transition point at about 950° C. It is very like cordierite. The effects of FeO on magnesian minerals and rocks are also considered.

"The Ternary System CaO–MgO–SiO_2," by J. B. Ferguson and H. E. Merwin. Proc. Nat. Acad. Sci., vol. v, pp. 16–18, 1919.

A very brief summary of a hitherto undescribed portion of this system by the quenching method. The phases found include, among others, cristobalite, tridymite, pseudowollastonite, periclase, forsterite, monticellite, diopside, and various solid solutions. One hitherto unrecorded compound is probably åkermanite. The temperature-concentration relations are shown in a triangular diagram.

"Temperature Viscosity Relations in the Ternary System CaO–Al_2O_3–SiO_2," by A. L. Field & P. H. Royster. Trans. Amer. Inst. Min. Eng., vol. lviii, pp. 658–68, 1918.

A study of the viscosity of slags, with reference to blast-furnace work. Measurements of viscosity show the existence of definite compounds in slags and even indicate their fields of stability. The maxima of viscosity occur at quintuple points and the minima at the binary eutectics.

"The Significance of Glass-making Processes to the Petrologist," by N. L. Bowen. Journ. Wash. Acad. Sci., vol. viii, pp. 88–93, 1918.

Observations during war-work at the Bausch-Lomb glass plant are applied to elucidate inhomogeneity in silicate melts. Liquid immiscibility and the Gouy-Chaperon principle are regarded as inapplicable, and differentiation is referred to rising of crystals and sinking of heavy liquid.

"A Type of Igneous Differentiation," by F. F. Grout. Journ. Geol., vol. xxvi, pp. 626–58, 1918.

The rocks of the Duluth intrusions fall into two series, gabbroid and granophyric (red rock). The evidence suggests an immiscible separation of acid and basic portions, the variations in the gabbro being produced by convection. The evidence is strong that differentiation of two kinds may occur in a single magma-chamber.

"The Lopolith: an Igneous Form exemplified by the Duluth Gabbro," by F. F. Grout. Amer. Journ. Sci., vol. xlvi, pp. 516–22, 1918.

The Duluth gabbro differs from typical laccoliths in that its central part is sunken, not raised. It is about 140 miles across, covering an area of about 15,000 square miles, and its volume is estimated at 50,000 cubic miles. It is intruded along the base of the Keweenawan. It is compared to the igneous masses of Sudbury and the Bushveld, and possibly of Skye and Julianehaab. For such saucer-shaped masses the name "lopolith" is suggested.

"The Charnockite Series of Igneous Rocks," by H. S. Washington. Amer. Journ. Sci., vol. xli, pp. 323–38, 1916.

Analyses, supplementary to Holland's descriptions, are given of five specimens of typical rocks of the Charnockite series, selected by the Indian Geological Survey. The relations of the Charnockites to the rocks of similar petrographic provinces are discussed somewhat fully.

"Geological Observations in Fiji. Part II: Petrography of Fiji," by W. G. Foye. Proc. Amer. Acad. Arts and Sci., vol. liv, pp. 97–145, 1918.

Petrographic descriptions are given of a large number of rocks collected by the writer in the islands of the Fiji group. They include tonalite, gabbro, porphyrite, pitchstone, andesite, basalt, and various pyroclastic types. Besides the plutonic intrusions four periods of extrusion are recognized, grading from acid to basic, all types being subalkaline and probably differentiates of a basaltic magma.

"The Nepheline Syenites of Haliburton County, Ontario," by W. G. Foye. Amer. Journ. Sci., vol. xl, pp. 413–36, 1915.

A petrographic description of two differentiated laccoliths of nepheline syenite, together with a discussion of the origin of such rocks in general: it is supposed that the solutions that gave rise to them were produced by the reaction of limestone with granitic magma.

"Eruptive Rocks at Cuttingsville, Vermont," by J. W. Eggleston. Amer. Journ. Sci., vol. xlv, pp. 377–410, 1918.

This small complex includes a large number of alkaline types ranging from essexite to nordmarkite, with their accompanying apophysal and complementary dykes. They are very similar to the rocks of Mount Ascutney, Red Hill, and Essex County in New England, and to the bosses of the Monteregian province, Quebec.

"The Origin of Serpentine: a Historical and Comparative Study," by W. N. Benson. Amer. Journ. Sci., vol. xlvi, pp. 631–731, 1918.

Chrysotile and antigorite serpentines are alteration products of peridotites, more or less pyroxenic; the hydration being often brought about by waters from the same magma. Sometimes it is due to water from later intrusions or to the general underground circulation. An extensive bibliography of serpentine is appended.

"Magmatic Differentiation in Effusive Rocks," by S. Powers and A. C. Lane. Trans. Amer. Inst. Min. Eng., vol. liv, pp. 442–57, 1917.

An investigation of gravitative differentiation-phenomena in effusive rocks shows a concentration of leucocratic minerals near the top and of melanocratic minerals near the base of the flows, while chilled margins show the original composition.

"Triassic Igneous Rocks in the vicinity of Gettysburg, Pennsylvania," by G. W. Stose and J. V. Lewis. Bull. Geol. Soc. Amer., vol. xxvii, pp. 623–44, 1916.

Subsidence and faulting of Triassic sediments was followed by intrusion of prevalently diabasic magma, its products ranging from olivine diabase through hypersthene diabase to quartz diabase, or even nearly pure quartz-felspar micropegmatite rocks.

"Hypersthene Syenite and Related Rocks of the Blue Ridge Region, Virginia," by T. L. Watson and J. H. Cline. Bull. Geol. Soc. Amer., vol. xxvii, pp. 193–234, 1916.

This petrographic province, which is probably of pre-Cambrian age, comprises a batholith about 150 miles long by 20 miles wide, composed of differentiates of a syenitic magma; the chief types are quartz-hypersthene syenite, granite, norite, gabbro, pyroxenite, and a quartz-felspar-epidote rock.

"Zircon-bearing Pegmatites in Virginia," by T. L. Watson. Trans. Amer. Inst. Min. Eng., vol. lv, pp. 936–42, 1917.

Pegmatites from Amelia County contain zircon, with beryl, helvite, allanite, columbite, and monazite, while those from Hanover County are specially characterized by zircon and rutile.

"The Emerald Deposits of Muzo, Colombia," by J. E. Pogue. Trans. Amer. Inst. Min. Eng., vol. lv, pp. 910–34, 1917.

A detailed description of the emerald deposits and their associated minerals with an account of the present state of the mining industry. The origin of the emeralds is ascribed to mineralization associated with intrusion of pegmatites.

REVIEWS.

I.—Les Echinides des "Bagh Beds". By R. Fourtau. Records Geol. Surv. India, vol. xlix, pt. i, pp. 34–53, pls. i, ii, 1918.

THE age of the marine Cretaceous series of the lower part of the Narbada Valley, generally known as the Bagh Beds, has long been regarded as Cenomanian, a view based to a large extent on Duncan's researches on the Echinoids. Other views of their age have been expressed, notably those of Stoliczka and of Bose, who both considered that more than one Cretaceous horizon was represented. At the time of Duncan's writing the Echinoids were the only group of fossils from these beds that had been critically examined, but Mr. E. W. Vredenburg has since studied the Ammonites, although he found that they did not help in determining the exact age of the beds.

The specimens upon which Duncan based his conclusions have lately been re-studied by M. R. Fourtau, whose results are valuable because they determine more accurately the relationships of these Echinoids, and also fix the age of the beds with more certainty. Duncan was so convinced by the general facies of the Echinoids that he was dealing with an undoubted Cenomanian fauna, that he did not find it necessary to make comparisons with older forms. M. Fourtau, on the other hand, was much puzzled by the record of two of the species, *Salenia fraasi* and *Echinobrissus goybeti*, since they belong to an horizon which R. P. Zumoffen has recently shown to be synchronous with the Aptian of the Mediterranean border. He has therefore made comparisons with a wide range of species in the Cretaceous, and he concludes that the Echinoids have affinities with the Early and Middle Cretaceous forms, that the Bagh Beds are of

Albian age, and that only one horizon is represented in the series. He thinks that the presence of *Placenticeras mintoi*, Vredenburg, confirms the reference of the beds to the Albian stage, since this Ammonite is related to *P. uhligi*, Choffat, from the Bellasian of Portugal, and to *P. saadense*, Peron & Thomas, from the Vraconnian of Northern Africa.

M. Fourtau gives a careful description of the eight species found in the Bagh Beds. He identifies Duncan's *Cidaris namadicus* [*sic*; the termination should be feminine] as a true *Dorocidaris*. In the case of *Salenia fraasi* the original diagnosis by Cotteau was not precise, hence later workers were misled, but M. Fourtau now shows that the form from the Bagh Beds is not the same as that from the Aptian of Lebanon. The new name *S. keatingei* is proposed for the species described by Duncan, which is regarded as closely comparable with *S. mamillata*, Cotteau, from the Aptian of France. The *Cyphosoma* from the Bagh Beds, which Duncan determined as *C. cenomanense*, Cotteau, is now called *C. namadicum*, n.sp., and the nearest related species is *C. peroni*, Cotteau, from the Barremian of France and Switzerland. The name *Orthopsis indica*, Duncan, still stands; the species is now compared with *O. repellini*, Desor, from the Barremian and Aptian of France, Switzerland, and Portugal. M. Fourtau regards the two large specimens of *Echinobrissus goybeti*, Duncan *non* Cotteau, and the two small deformed *E. similis*, Duncan *non* d'Orbigny, as of the same species, and proposes the new name *E. haydeni*. The nearest allied species is *E. eddissensis*, Gauthier, from the Aptian and Albian of Algeria and Tunis. *Hemiaster cenomanensis*, Duncan *non* Cotteau, is redescribed as *H. oldhami*, n.sp., and the most closely related species is *H. luynesi*, Cotteau, from the Cenomanian of Palestine. Other examples of *Hemiaster* were referred by Duncan to *H. similis*, Orbigny, of which a figure was subsequently reproduced by Mr. R. D. Oldham in his *Geology of India*. Of the five specimens sent to M. Fourtau, three are separated and described as *Opisaster subsimilis*, n.sp., and regarded as related to *O. morgani*, Cotteau and Gauthier, from the Senonian of Persia. The other two are described as *Opisaster*, sp. indet., a form related to *O. vignesi*, Cotteau, from the Cretaceous of Palestine.

C. P. C.

II.—Yacimientos Carboníferos de las Provincias de Pallasca, Huaylas y Yungay. By Juan M. Yañez Leon. Boletin del Cuerpo de Ingenieros de Minas del Peru, No. 90, pp. 85, with 5 plates and 2 maps. 1918.

THE stoppage of the import of foreign coal into Peru has served to call attention to the potential value of native supplies, and in this memoir the author gives an account, both scientific and economic, of the large supplies of high-grade coal that exist in the provinces of Pallasca, Huaylas, and Yungay. The coal occurs in strata of Lower Cretaceous (Wealden) age, forming three seams averaging about 1, 2, and 1 metres respectively, separated by varying thicknesses of sandstones, shales, and limestones. As shown by the sections given the strata are considerably folded, and

in some localities the dips are as high as 60°, though over a considerable area the beds are nearly flat. The coal is of anthracitic character, averaging about 79 per cent of fixed carbon, 10 per cent of volatile matter, and 6 per cent of ash, with a calorific power of about 13,770 B.T.U. It is of good quality, well suited for industrial uses, although possessing poor coking properties. A highly conservative estimate gives a workable quantity of 152,900,000 tons, allowing an abundant margin for all contingencies in working.

A brief account is also given of the tungsten ores of Huaura, and of a newly discovered region in the neighbourhood of Tarica, as well as of the copper deposits of Magistral.

R. H. R.

III.—Special Reports on the Mineral Resources of Great Britain. Vol. VII: Lignites, Jets, Kimmeridge Oil-shale, Mineral Oil, Cannel Coals, Natural Gas. Part I: England and Wales. By A. Strahan. Mem. Geol. Survey, pp. 69, with 1 plate and 3 text-figures. 1918. Price 2*s.* 6*d.*

DURING the last four years there has been a vast amount of irresponsible talking and writing about the possibility of the discovery of workable sources of oil and other natural fuels, other than coal, in the British Isles. It is, therefore, highly satisfactory to find that the Geological Survey has collated all known information on the subject, examining the records of past operations so far as available, and in the case of present explorations, carrying out independent investigations on the spot. The scope of the Memoir is sufficiently indicated by its title. The most important sections deal with the lignites of Bovey Tracey, the explorations made in them by Germans and others, and the uses to which they have been put; the distribution of Kimmeridge Oil-shale throughout the country; the principal known occurrences of mineral oil, cannel coal, and natural gas. It may be said at once in general terms that a careful perusal of this volume does not lend any notable amount of support to the highly optimistic views set forth in the daily papers during the last year or two.

A very full description is given of the well-known lignite and clay deposits of Bovey Tracey, and of the somewhat obscure operations of the German company, which mysteriously vanished two days before the declaration of war. It appears that the products of their industry were not of satisfactory quality, owing to the fact that the lignite consists mostly of highly resinous *Sequoia* wood, which seems to be unsuitable for the manufacture of paraffin wax and similar materials; the chief product of distillation being an evil-smelling yellow tar, a wholly unsaleable substance. Detailed sections are given of several borings put down in this area; these show the presence of a large amount of lignite, which is apparently only of poor quality and much mixed with clay. It is also shown that lignite has a wide distribution in Tertiary, Cretaceous, and Jurassic rocks, but nowhere in workable quantities. A brief account is given of the almost extinct Whitby jet industry.

A chapter of seventeen pages is devoted to a consideration of the Oil-shales of the Kimmeridge series, which have lately been the subject of much discussion. The observations here recorded are largely founded on the results of borings made by the Department for the Development of Mineral Resources. The possible oil-yielding bed, locally known as the "Blackstone", forms part of the upper division of the Kimmeridge, and was probably never laid down over much of the distance between Dorset and Cambridgeshire, coming in again as bituminous shales in Lincolnshire and Yorkshire. Numerous analyses are given of samples from Kimmeridge and Corton, in Dorset, and from Donnington-on-Bain, in Lincolnshire. The yield of oil varies from 13 to 39 gallons per ton, and of sulphate of ammonia from 11 to 32 lb. per ton in Dorset, the figures for Lincolnshire being much lower.

The well-known occurrence of natural gas at Heathfield, in Sussex, is described, as well as other instances met with in borings at Calvert, in Bucks, and near Middlesbrough, which appear to be unimportant. From a statement in the preface it appears that this memoir is to be regarded as an instalment, and that a further publication on the subject of mineral oil in Britain is in contemplation.

R. H. R.

IV.—Eindverslag over de Onderzoekingen en Uitkomsten van den Dienst der Rijksopsporing van Delfstoffen in Nederland, 1903–1916. 664 pp. Amsterdam, 1918.

THIS immense volume contains the final report on the investigations that have been carried on in the Netherlands in search of coal and other useful minerals, chiefly under the direction of Mr. W. A. J. M. van Waterschoot van der Gracht, a geologist well known in England. In 1903 the Government made a grant of 3,000,000 gulden for this purpose: the total cost for 25 deep bores and all expenses was about 2,500,000 gulden. Coal-measures were actually reached in three areas: (1) In the Peel district in the middle and north of Limburg coal was proved at a less depth than 1,200 m. over an area of 19,500 hectares; it is estimated that seams of workable thickness contain 1,766,000,000 tons, while a further 799,000,000 tons below 1,200 m. may possibly be workable in the future, though not immediately available. (2) In the Winterswijk district in East Gelderland 300,000,000 tons of coal exist at depths not greater than 1,400 m., and an enormous amount of rock-salt was also proved. (3) The most important coalfield is, however, in South Limburg, where coal occurs at a less depth than 1,200 m. over an area of at least 37,000 hectares. The coal is classified according to its gas content, in the German manner, and the reserves are estimated as follows:—

	Tons.
Over 35 per cent gas content . .	206,000,000
35–30 ,, ,,	483,000,000
30–20 ,, ,,	1,396,000,000
20–14 ,, ,,	927,000,000
below 14 ,, ,,	1,541,000,000
	4,553,000,000

Hence the whole coal reserves of the Netherlands, probably workable under present engineering and economic conditions, amount to 5,256,000,000 tons, without taking into account supplies that may become available at a later date. In the Buurse-Hengele district in the south-east of Overijssel, the coal was found to lie too deep, but important beds of rock-salt were encountered. The vast deposits of salt found both here and in the Winterswijk district suggest the possibility of finding both potash salts and petroleum.

The report gives a detailed account of the stratigraphy and palæontology of the beds passed through by the borings, the palæobotany being dealt with by Dr. W. J. Jongmans. The local development of the strata is carefully compared with those seen in France, Belgium, and Westphalia. The Upper Carboniferous is divided into four groups, respectively designated the Maurits, Hendrik, Wilhelmina, and Baarlo stages, in descending order. Each of these appears to be characterized by a special assemblage of fossil plants.

The whole investigation affords an admirable example of far-seeing and well-directed enterprise, and both the Government and the staff employed are to be congratulated on the results obtained, which seem likely to lead to important commercial developments in the near future, possibly rendering Holland economically independent of foreign supplies of coal. The sufferings of the country in the last four years will doubtless stimulate efforts in this direction in view of a possible repetition of such conditions in the event of a future war.

R. H. R.

V.—Note on the Aquamarine Mines of Daso, Baltistan. By C. S. Middlemiss and L. G. Parshad. Rec. Geol. Surv. India, vol. xlix, pt. iii, pp. 161–172, with 5 plates, 1918.

IN 1915 an important deposit of aquamarine was located at Daso, on the Braldu River, Shigar Valley, Baltistan, Kashmir, and it is now being actively exploited. The country rock for miles round is biotite-gneiss with big veins of coarse pegmatite, consisting of quartz, orthoclase with some albite, tourmaline, muscovite, garnet and beryl. The best and most transparent beryls are found in drusy cavities, and the prisms are often up to 3 inches long, while crystals of opaque varieties may be as much as 6 inches in length. The colour of the best specimens is not very deep, but of the true aquamarine shade. The available supply appears to be very large, but mining is somewhat handicapped by high transport charges for stores and equipment.

VI.—Observaciones Geológicas en la Isla de Gomera (Canarias). By L. F. Navarro. Trab. Mus. Nac. Cien. Nat., Geological Series No. 23, pp. 87, with 34 text-figures and a map. Madrid, 1918.

THE author has paid several visits to this little-known island, of which he describes the topography and geology in some detail. The island is remarkable for the abruptness of its shores and the general steepness in its slopes. It is deeply dissected by a large number of

"barrancos", steep valleys of characteristic form with passes at their heads affording means of access from one part of the island to another. The author also discusses with particular care the origin of the peculiar isolated peaks and platforms of phonolite, locally called "roques" and "fortalezas", and discourages the tendency to explain them all without discrimination as spines of the Peléan type, although admitting that a few of them may be such. Petrographic descriptions are given of the rock-types observed, which include augite-andesite, basalt, ægirine-phonolite, trachy-phonolite, trachyte, sanidinite, and trachyandesite, with corresponding tuffs and breccias.

R. H. R.

VII.—Petrographische Beschreibung einiger Basalte von Patagonien, Westantarktika und den Süd-Sandwich Inseln. By O. Baeckström. Bull. Geol. Inst. Univ. Upsala, vol. xiii, pt. ii, p. 115, 1916.

AN elaborate petrographical description of basalts from various localities in Southern Patagonia, from Ross Island, Cockburn Island, Paulet Island, and other localities in the western part of Antarctica, together with the South Sandwich Islands. The general characteristics of most of the area described are somewhat indefinite from the petrographic point of view, since calc-alkali basalts are widely distributed, but commonly associated with rocks of distinctly alkaline and Atlantic type. In the South Sandwich Islands, however, alkaline rocks are wholly wanting, indicating a connexion with the calc-alkaline Pacific province.

VIII.—Scope and Significance of Paleo-ecology. By Frederic E. Clements. Bull. Geol. Soc. Amer., vol. xxix, pp. 369–74. June 30, 1918.

THE title of this paper is promising, but the performance is unsatisfying. "Paleo-ecology," says the author, "is characterized by its great perspective, due chiefly to the absence of a large body of facts." The meaning of this is obscure, unless it is that the wood is easily seen because there are so few trees. The author's chief points, so far as we can extract them from an abundance of words, are that vegetation should first be studied because it is the connecting link between the topography and the fauna; secondly, that valuable results may be expected from the study of successive floras and faunas in a limited area. It will be gathered that Mr. Clements' attention is focussed on epi-continental formations (forgive the mongrel term!), such as the badlands and lacustrine deposits of North America. From there some interesting facts and inferences are cited.

IX.—Mineralogy of the H.B. Mine, Salmo, B.C. By T. L. Walker. University of Toronto Studies, Geol. Ser., No. 10, 1918.

THE minerals, calamine, spencerite, hopeite, and parahopeite, formed by the oxidation of zinc ores in a marmorized limestone are described. From an examination of the optical properties

spencerite had previously (*Min. Mag.*, **18**, 76, 1916) been classed as monoclinic, and this is now confirmed by goniometrical measurements. The relationships of the various hydrated zinc phosphates are briefly discussed.

A. S.

X.—Notes on Mimetite, Thaumasite, and Wavellite. By E. T. Wherry. Proc. U.S. Nat. Mus., **34**, 373–81, 1918.

THE crystals of mimetite described are of unusual habit and rich in forms, several of which are new. A "prism" determination of the mean refractive index gives the value 2·14, agreeing with previous values obtained by the immersion method. New forms were also observed on thaumasite, which is regarded by the author as a sulphate. Wavellite rarely occurs in measurable crystals, but in this instance the development is sufficiently good for the crystals to be measured, the axial ratios being 0·345 : 1 : 0·404. The refractive indices and chemical composition are also determined.

A. S.

XI.—Augite from Stromboli. By S. Kozu and H. S. Washington. Amer. Journ. Sci. (4), **45**, 463–9, 1918.

THE results of chemical and optical examinations of the augite, occurring in the ashes round Stromboli, are given. In chemical composition it closely resembles other Mediterranean augites, as 80 per cent consists of the diopside molecule, the remaining molecules being acmite, hypersthene, and an aluminous compound in nearly equal proportions. The refractive indices for sodium light are, α 1·693, β 1·699, γ 1·719, while the optical axial angle (2V) is 57° 39.

A. S.

XII.—United States National Museum.

THE annual report on the United States National Museum for the year ending June 30, 1917, published by the Smithsonian Institution, includes an account of the additions made to the Department of Geology during that time. The Department was specially fortunate in the acquisition of meteorites, having received by bequest the well-known and important Shepard Collection. Other noteworthy accessions were specimens of ores of metals used for hardening steel, namely tungsten and vanadium. A large number of good mineral specimens and gem-stones were transferred from the Geological Survey, and the palæontological collections were enriched by the addition of a large number of type-specimens.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. Parts of the Report of the Annual General Meeting on February 21, 1919, having already appeared in the Geological Magazine (see March Number, pp. 97, 98, and April Number, pp. 145–6), it is obviously needless to repeat them in further detail here.—Editor.

2. *February* 26, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The President said in accordance with the Special Notice it was proposed to change the subject previously announced for the afternoon's meeting, and he hoped the change would be approved, namely, that Colonel T. W. Edgeworth David, D.S.O., C.M.G., D.Sc., F.R.S., would deliver a lecture on "Geology at the Western Front".

After the lecture a vote of thanks was unanimously accorded to Colonel David for his lecture.

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3. *March* 12, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The following communication was read by Mr. R. D. Oldham, F.R.S., in the absence of the author:—

"The Early History of the Indus, Brahmaputra, and Ganges." By Lieut. Edwin Hall Pascoe, I.A.R.O., M.A., D.Sc., F.G.S., Superintendent Geological Survey of India.

The occurrences of marine Nummulitic rocks show that in Eocene times a gulf of the sea extended up the Indus valley and the hill country to the west of it, and eastwards along the southern margin of the Himalayas at least as far as the neighbourhood of Naini Tal. In the Himalayan region the marine deposits are succeeded by a series of red clays with intercalated sandstones and occasionally marine beds, regarded by the author as having been deposited in a series of lagoons. The Upper Tertiary deposits consist of a great series of conglomerates, sandstones, and silts of freshwater origin, which are known to extend along the whole of the southern face of the Himalayas. From these geological indications the author concludes that the first effect of the commencement of the Himalayan uplift was the establishment of a great westward-flowing river along the southern face of the range, for which he proposes the name of Indobrahm. The distribution of Tertiary rocks on the northern side of the range suggests that here also a westward-flowing river was formed, which discharged either round the end of the range into the same sea as the Indobrahm, or flowed westward into the region of Turkestan and the Caspian Sea. The subsequent history of the drainage system consists of the capture of the upper waters of this river by a tributary of the Indobrahm, a cutting-back along the valley to form the eastward flowing Tsangpo, now the upper waters of the Brahmaputra, and the capture of the lower reaches in part by the Sutlej and in part by the Attock tributary of the Indobrahm, to form the Himalayan portion of the Indus valley. Meanwhile, on the southern side of the range, some of the tributaries on the eastern side of the Lower Indobrahm had cut back from the Sind region and cut off the original bend near Attock, to form the present plains of the Punjab; and farther east, a river cutting back along the present line of the Gangetic delta and lower course of the Ganges and Brahmaputra, had captured the upper waters of the Indobrahm to form the present Brahmaputra. The same system of capture had worked westwards, until the tributaries of the Indobrahm had been

successfully diverted from a westerly to an easterly drainage up to and including the Jumna River. The author finds proof of the recent date of the separation between the drainage-system of the Indus and that of the Ganges in certain historical evidence, indicating that the Jumna was a tributary of the Indus within the human period; in the occurrence of the same species of freshwater porpoise in the two river-systems and nowhere else outside of them; and in the identity of the freshwater Chelonia of the two river-systems, the species being either peculiar to these drainage-areas or represented outside of them by distinct varieties.

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4. *March* 26, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

At 6 p.m. a special general meeting was held in order to consider the following resolution of Council: "That it is desirable to admit Women as Fellows of the Society."

The President said: It will be within the recollection of most of the Fellows that the question of the admission of women to candidature for the Fellowship of the Society has been raised on more than one occasion in the past. It was considered in 1889 and 1901, and again, more systematically in 1908–9, when a poll of the Fellows was taken and three special general meetings were held, with inconclusive results.

It is generally recognized that the course of events since these dates has materially changed the situation. Women have been welcomed to our meetings as visitors, and we have had many examples of their qualifications for Fellowship in the excellent papers which they have from time to time contributed to the Society. The value of these papers has been appreciated by all geologists, and has been repeatedly acknowledged by the Council in its awards.

Therefore, in the opinion of the Council, it is no longer reasonable to maintain a sex-bar against qualified candidates for the Fellowship of the Society, and I am empowered by the Council to submit the above-mentioned resolution for your consideration.

A ballot was then taken, and the resolution was declared carried by 55 votes against 12.

II.—The Royal Society.

March 27, 1919.—Sir. J. J. Thomson, O.M., President, in the Chair.

The following paper was read:—

"The Morphology and Evolution of the Ambulacrum in the Echinoidea." By H. L. Hawkins, M.Sc., F.G.S. (Communicated by Dr. Henry Woodward, F.R.S.)

A summarized account of the ambulacra in non-Holectypoid orders is given. *Bothriocidaris* shows the simplest type of structure, and the most efficient for coronal strength. As podia increased, ambulacral plates multiplied, and the areas became mechanically weak. The main podial function in Regular Echinoids being adhesive, coronal weakness demanded modification. In most Palæozoic types, general

flexibility neutralized local weakness; but with the adoption of rigidity the problem reappeared. Hence arose "plate-complexity".

The formation of compound plates is discussed. "Grouping" precedes, and is distinct from, combination. Plate-reduction is due to "growth-pressure"; combination to tubercle-growth. Elaboration of combination culminates in the Echinometridæ, where the compounds regain "Bothriocidaroid" proportions.

In irregular Echinoids no combination occurs; grouping is often developed. Secondary specialization in Spatangids produces "Palæozoic" structures.

The Holectypoida show four ambulacral types:

(1) Plesiechinid (triad-groups adorally, primaries adapically);
(2) Pygasterid (primaries throughout);
(3) Pyrinid (triad-groups throughout);
(4) Discoidiid (triad-groups adorally, dyad-groups adapically).

Plesiechinid is primitive, and resembles the early Acrosaleniid type. Pygasterid indicates simplification, being morphogenically transitional from Diademoid to Spatangid structure. Pyrinid is persistent, resembling the "Echinoid" structure of Diademoids. Discoidiid is exceedingly elaborate, showing extreme plate-reduction.

The Cassiduloidea are divided into Nucleolitoida and Cassiduloida (restr.). The former order is related to the Pygasteridæ; its simpler members have Plesiechinid ambulacra, and Holectypoid structures appear in later forms. The Cassiduloida evolved through the Echinonëidæ.

There are three main trends of evolution in Echinoid ambulacra: (i) Diademoid, attaining plate-combination; (ii) Clypeastroid, attaining plate-destruction; and (iii) Spatangoid, reversionary.

III.—Edinburgh Geological Society.

February 19, 1919.—Professor Jehu, President, in the Chair.

1. "A Historical Sketch of the Iron Industry in Scotland." By M. Macgregor, M.A., B.Sc., of H.M. Geological Survey.

Mr. Macgregor sketched the rise and development of iron-working in Scotland, more particularly in regard to the raw materials used. The small primitive furnaces of early times known as *Bloomeries* were described, and an account was given of the iron-works in operation in the Loch Maree district during the first half of the seventeenth century. The later furnaces in the central and west Highlands during the eighteenth century were then noticed in some detail. In all these, charcoal was used as fuel. The smelting of Scottish Carboniferous clayband ores by means of coke and coal came into vogue soon after 1750, the year in which the Carron Ironworks began their long career. Since that time there had been three main stages in the development of the modern iron industry. These were as follows: (1) Rise of the Clayband Industry, 1760–1830; (2) Rise of the Blackband Industry, 1830–60; (3) Rise of the open-hearth Steel Industry, and period of imported ores, 1850 onwards.

2. Exhibition of Specimens of Norwegian Nepheline Syenite (Laurdalite) Boulders from Flotta, Orkney. By Dr. J. S. Flett, F.R.S.

IV.—Mineralogical Society.

March 18.—Sir William P. Beale, Bart., K.C., President, in the Chair.

L. J. Spencer: "Curvature in Crystals." The curvature of crystals is evidently of many different kinds, and due to as many different causes. Numerous examples, figured in the literature and illustrated by specimens in the British Museum collection of minerals, are grouped under the headings: curved crystallites and feathery microlites, capillary habit, aggregations of crystals, interfacial oscillation, vicinal faces, bent crystals and plastic deformation, twisted crystals, cylindrical (?) and spherical (?) crystals (a supposition leading to a *reductio ad absurdum*).

Lieut. A. B. Edge: "Siliceous Sinter from Lustleigh, Devon." The district round Lustleigh, near Bovey Tracey, is mined on a small scale for a very fine quality of micaceous hematite, which occurs there in well-defined lodes traversing the granite. At the Plumley Mine (now disused), on the walls of one of these lodes, is found a peculiar banded material, somewhat resembling lithomarge or halloysite, which on analysis proved to be a siliceous sinter or opal, with an approximate percentage composition of silica 70, water 21, hematite 6, alumina, soda and potash 3, and a low specific gravity, 1·73. It is hard and compact, and shows a beautifully banded structure, the layers being tinted to varying degrees by limonite and finely divided flakes of micaceous hematite. The general appearance of the material and the presence of delicately overfolded ripples in the banding suggest that it was originally deposited on the walls of the lode in the form of a jelly, and solidified by loss of water. Such loss continues at a very slow rate when specimens are kept in a dry atmosphere, and after some years the surface becomes soft and powdery. The sinter is very fragile, breaking conchoidally even when most carefully handled; this may be caused by the shrinkage strains set up during solidification. The source of this hydrated silica is rather doubtful; it probably formed part of the aqueous injection which deposited the hematite, but may possibly have been leached from the granite during the formation of the lode.

A. F. Hallimond: "An Anorthic Metasilicate from Acid Steel Furnace Slags." A description of the slags will be communicated to the Iron and Steel Institute. The substance is a metasilicate of iron, manganese, calcium, and magnesium, and appears as flat, elongated crystals with the following characters: Forms $b(010)$, $m(110)$, $M(1\bar{1}0)$, $p(1\bar{1}2)$, $l(10\bar{1})$, $n(3\bar{1}0)$, constants α 99° 37′, β 110° 57′, γ 82° 3′; $a:b:c = 1{\cdot}156:1:0{\cdot}497$; perfect cleavages parallel to m and M, $mM = 95°\,9\frac{1}{2}'$; colour clear amber yellow, not pleochroic; optical characters, $2V = 65\frac{1}{2}°$, negative, $\beta = 1{\cdot}701$, axial plane nearly normal to the cleavage zone, extinction on a 5°, acute bisectrix nearly normal to a.

Dr. C. T. Prior: "On the Meteorites Adare and Ensisheim." The percentage amount of nickeliferous iron and the ratio of iron to nickel in it were found to be respectively 18 and 13 in the case of Adare, and $3\frac{1}{2}$ and $3\frac{1}{2}$ in the case of Ensisheim, which results support